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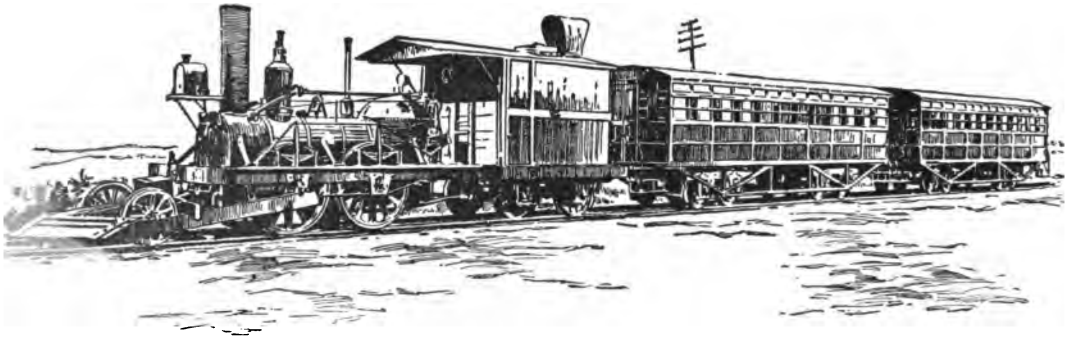
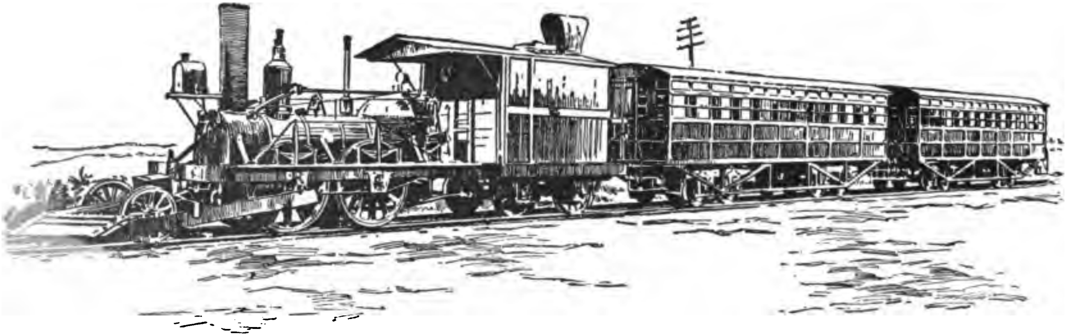


THE "JOHN BULL" AND ITS TRAIN, 1831.

Cylinders, 9" × 20".
Gauge, 5' (original).
Boiler, 13' long, 3' 6" diameter.
Driving-wheels, 4' 6".
Present Gauge, 4' 8½".
Weight of Engine, 22,000 lbs.

PENNSYLVANIA RAILROAD.



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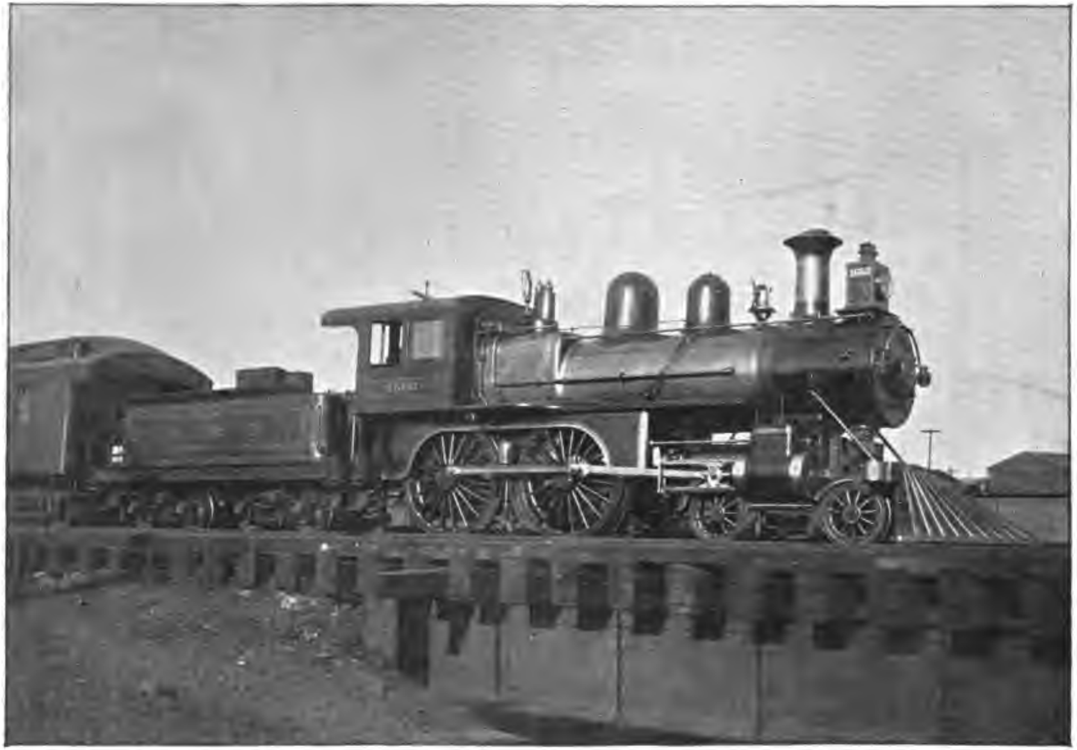
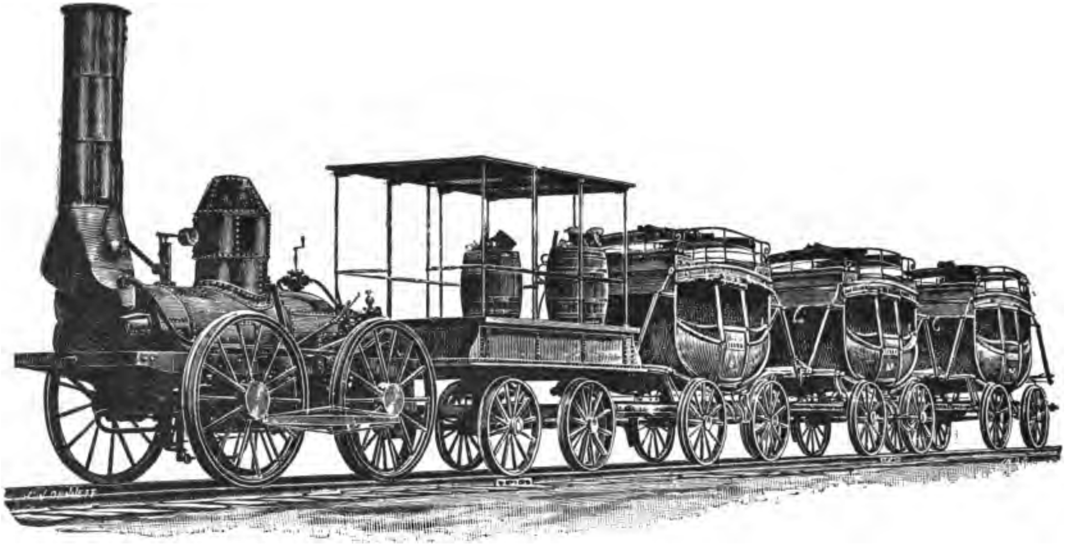
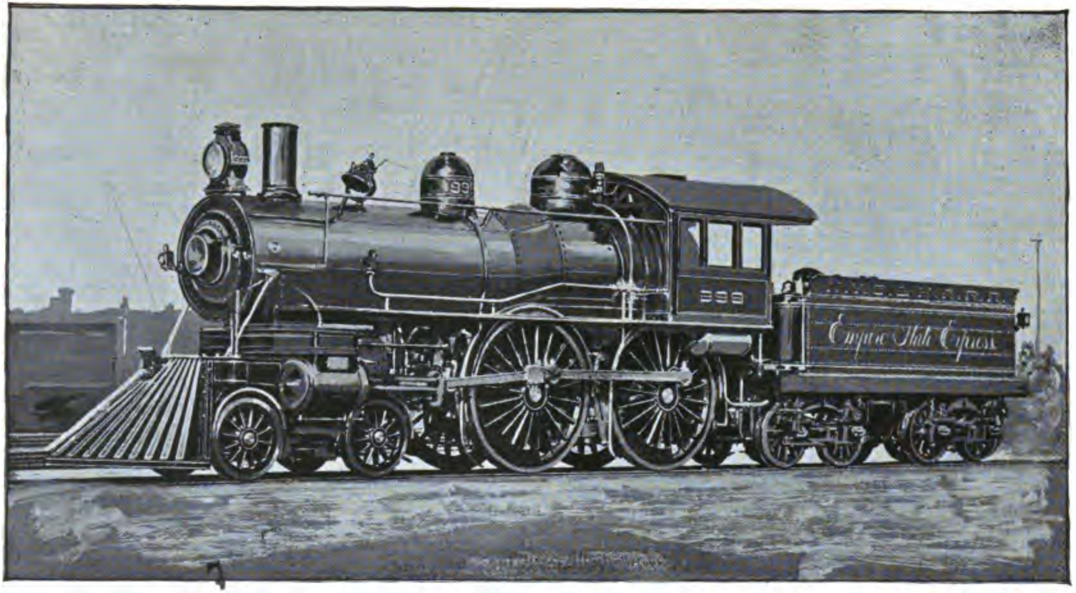


Engine for Pennsylvania Railroad.

Diameter of Cylinders, 19½" × 24" stroke. Diameter of Drivers, 78".
Boiler-pressure, 175 pounds. Weight on Drivers, 80,600 lbs.



The "De Witt Clinton," New York Central Railroad, 1831.



ENGINE 999, NEW YORK CENTRAL RAILROAD, 1893.

Diameter of Cylinders, 19″ × 24″ stroke. Diameter of Drivers, 87″.
Boiler-pressure, 180 pounds. Weight on Drivers, 82,200 pounds.
Speed, 102 miles per hour.

LOCOMOTIVE MECHANISM

AND

ENGINEERING.

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H. C. REAGAN, JR.,

Locomotive Engineer.

FIRST EDITION.
FIRST THOUSAND.

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THIS BOOK

IS RESPECTFULLY DEDICATED TO THOSE

Locomotive Engineers and Firemen

WHO ARE TRYING TO INCREASE THEIR KNOWLEDGE OF THE STEAM
POWER UNDER THEIR CONTROL, DECREASE THE CHANCE
OF ACCIDENT, INCREASE THE SAFETY OF HUMAN
LIVES, AND GIVE GREATER SATISFACTION
TO THEIR EMPLOYERS,

BY

THEIR FRIEND THE AUTHOR,

WHO IS PRACTICALLY
ONE OF THEM.

PREFACE.

THE author, who is a practical engineer, attempts in this book to write a practical treatise on the Locomotive Engine, and has tried to describe the manner in which the locomotive is handled while in service.

There are many excellent books on the locomotive, but there is one portion of the subject which, in the author's opinion, has not yet been covered.

The man who wishes to understand an engine thoroughly will learn more by watching repairs made in the shop, or in case of accident on the road, when the engine is disconnected, than if the method were described to him in so many words; for he thus sees the actual construction, break, and repairs.

The author has illustrated this book with this purpose in view, and has made most of the drawings himself.

Where others are used due credit is given, and therefore it may be truly said the drawings represent actual practice.

The text contains also a full explanation of the drawings, questions are asked and answered on the construction of the locomotive and its performances, and complete directions are given as to what should be done in case of emergency.

The reasons for first explaining the construction and action and then asking and answering questions are three: first, when a question is asked and answered, and the reader does not thoroughly understand the construction and action of mechanism, the questions and answers will not be clear to him; second, the reader will be more vividly impressed by reviewing the questions and answers; third, the questions and answers are so arranged that the book can be used by Master Mechanics or Travelling Engineers for the examination of candidates for promotion, or by the demonstrator in the Lodge Room.

An effort has been made to present to the reader a full and clear explanation of the Compound Locomotive, showing the construction of different systems in actual use, and giving the method of disconnecting such engines when broken down.

The author has illustrated the principal "breakdowns" that happen to a locomotive, so that when one actually occurs on the road the engineer can compare the break with the illustrations in the book, and find out exactly what should be done.

Each part of the mechanism is named in the illustrations as a guide to the engineer in making out work reports.

I am indebted to the proprietors of the works whose Compound Locomotives are shown in this book, for drawings and photographs; to the Westinghouse and New York Air-crake companies, and other manufacturers whose appliances have been illustrated and described; and to the *Railroad Gazette* for part of the description of the Brooks Two Cylinder and Schenectady Compounds.

If the book fulfils the mission for which it was written, the author will consider that his labor has been rewarded.

H. C. REAGAN, JR.
Locomotive Engineer.

PHILADELPHIA, January, 1894.

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LOCOMOTIVE MECHANISM AND ENGINEERING.

CHAPTER I.

THE LOCOMOTIVE BOILER.

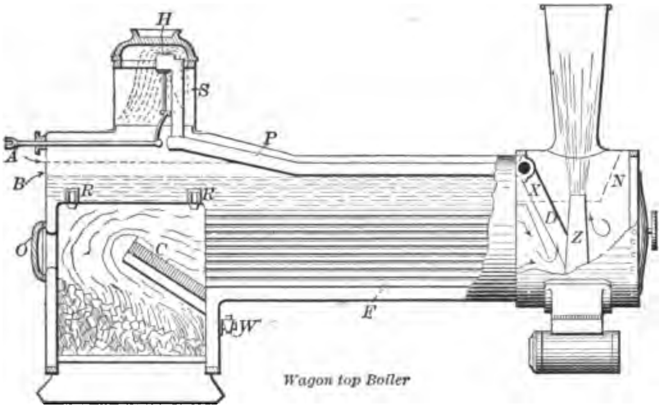
THE best subject with which to start is the lomocotive boiler, of which there are two illustrations. Fig. 1 is a wagon-top boiler. Fig. 2 is a Belpaire boiler, which is now being used on many roads.

The principal difference between them is the shape of boiler over fire-box, and the method of staying. In the Belpaire boiler the back end over fire-box is nearly square, there being a radius on the corner for bending. The Belpaire boiler also uses radial stays, thus obviating the necessity of using crown-bars and sling-stays; which seems an advantage, as it not so complicated, and the mud cannot accumulate on the crown-sheet, as it does when using crown-bars. The sheets can adjust themselves to each other better under different pressures and change of temperature.

The principal parts of a boiler are the fire-box, flues, dome, steam or dry pipe, throttle-valve, the smoke-arch in which are the steam-pipes leading to each steam-chest, the exhaust-nozzles, and the stack.

That portion of boiler which is over the fire-box must be very strongly stayed with either crown-bars or radial stays. The Belpaire boiler is strengthened in the latter manner. This staying is necessary from the large area and the exposure to the hottest part of the fire.

The dome is for the purpose of providing a reservoir for dry steam and in it the throttle-valve is placed as high as possible above the water-line, to prevent entrained water from being carried over into cylinder, which is detrimental to the engine, and might cause a cylinder-head to be knocked out, if in large quantities.



Wagon top Boiler

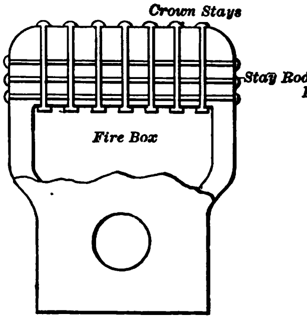
FIG. 1.

The throttle-valve is a double disk (Fig. 3) having two seats in the steam-pipe. The disks are of nearly the same diameter, in order to balance.

The top disk is the larger, so that the throttle will stay closed, due to the greater pressure on top, holding valve down to seat. The difference in area, however, is not sufficient to make the throttle open with difficulty.

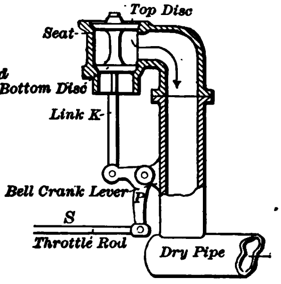
To the lower disk is attached a link *K*. This link is connected with a bell-crank lever *P*, which has its fulcrum on steam-pipe.

On the lower end of bell-crank lever is the throttle-rod *S*. To this on the outside of the boiler is the throttle-lever, which every ambitious fireman is anxious to control.



Belpaire Boiler Back End

FIG. 2.



Throttle Valve

FIG. 3.

The dry pipe is put into a boiler to carry dry steam to the cylinders, the steam entering the pipe at throttle-valve in dome. If this was not provided, the boiler would prime.

One of the most important things that an engineer should understand is the action of water in a boiler, and the effect of heat and impurities in the water. It often causes the student or beginner to wonder at the change of the water-line in a boiler when using and not using steam from it.

It will be found that after the throttle is opened the water in the boiler has raised one gauge or more. This is caused by the release of pressure on water-line on the opening of the throttle. The water being in a state of ebullition, due to the intense heat from the fire, expands. Fig. 1 at letter *B* shows the water-line when the throttle is closed; *A*, or dotted line, shows water when the throttle is open and using steam.

Another cause of water rising in the boiler is due to impurities in the water, such as salt, oil, soap, and vegetable matter. These produce foaming, and frequently cause a boiler to be burned and an engineer to lose his position.

It is also important that an engineer should be able to detect at the earliest moment the beginning of foaming. The symptoms are as follows: On trying the gauge-cock it will be found that water is gaining very rapidly, notwithstanding the fact that he has not readjusted his injector, or changed the point of cut-off in his cylinders. Also, if the engine is foaming very badly, water will appear at the stack, in a light lathery foam. If, then, the throttle is closed, the water will fall probably to the bottom gauge-cock, or below, and this is a dangerous action. Now if the water should fall below the bottom gauge, and the engineer is desirous of finding out where the water is, he should open the throttle suddenly or frequently by blowing the whistle, and if there is water near the bottom gauge-cock it will show. If water shows, the boiler should be filled up to top gauge, and the surface blow opened, keeping the injectors on while it is open, in order to keep the water-line up.

By doing this the water can be changed, and that which contains the impurities blown off.

It should be remembered that there is a difference between foaming and priming. Priming is caused by too much water in the boiler, or by a cracked, dry pipe, or by a dome of too small diameter.

When there is too much water in the boiler and the throttle is opened, the water is carried over with steam into the cylinder, as is shown in Fig. 1, in dome.

This is a very bad practice, and is far from economical. The water which is thus carried over contains heat, which is wasted, because this water which contains the heat does not expand to any considerable degree, and therefore does not give out any effective power, while it reduces the expansive force of the steam with which it mingles.

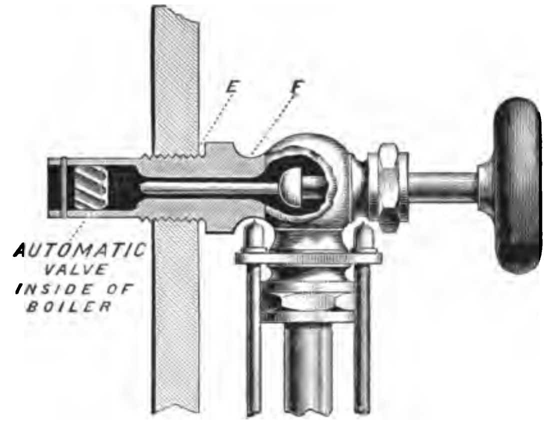
Remember, also, that dry steam is capable of doing more work than wet steam, and is therefore more economical, while with it there is less danger of breaking the engine down, or cutting valves and seats.

It is very important that all gauge-cocks should be kept open, and especially, under all circumstances, the bottom one.

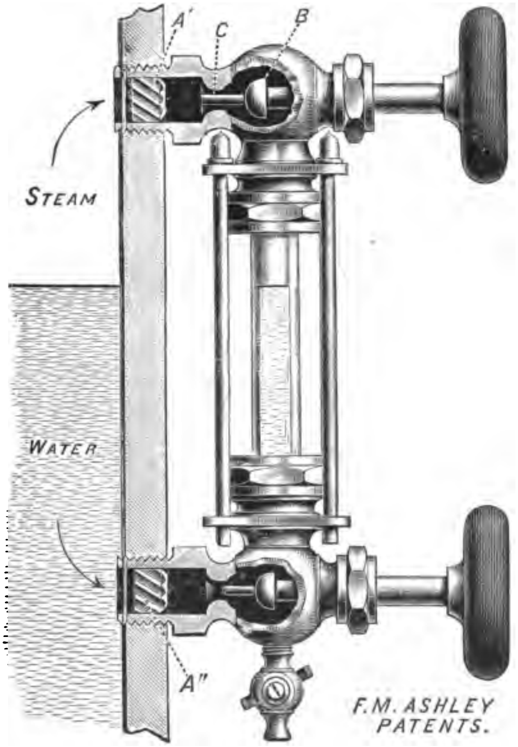
When water-gauge glasses are used, the glass and valves should be open and free, for it is dangerous for them to be clogged up, as the glass will not then register correctly.

Water-gauge glasses are equipped with automatic-closing valves, so that when from any cause the glass is broken the steam and water will not escape into the cab, scalding the engineer and fireman; also prevent the loss of water and endangering the crown-sheet, if broken when no one is around. The sketch at *A*, *A′* shows a very simple form of automatic valve. This valve will grind out any sediment that may collect on the seat. The grooves or wings are in the form of a spiral. By screwing the button or main valve towards the seat until the pin *C* extends through far enough to let the automatic valve come up against it, this forms an axis for valve *A*. By opening the pet-cock at bottom of glass, the steam will pass through the wings of automatic valves *A*, *A′*, causing them to revolve rapidly. Grind-seat and passage open the valve *B* wide when done grinding. Most all glasses have ball-valves which close automatically. Water in a gauge-glass should fluctuate freely with the water-line. If it does not do this, but stands motionless in the glass, the valves are clogged up and should be blown out. It is policy to do this before starting out, on each trip.

The fire-box needs very little explanation, as its purpose is evident to all; but most fire-boxes are equipped with brick arches, which improve combustion by maintaining the gases at an igniting temperature. This is due to the brick becoming incandescent, and also to the brick deflecting the cold air as it comes into the fire-door when open, and preventing it from rushing into the flues and chilling the gases. Fig. 1 shows the course of the gases to the smoke-box, and the appliances therein, as will be seen by referring to the drawing. *D* is the diaphragm, which serves the purpose of regulating the draught through flues and in fire-box. If the diaphragm was not used, the draught would be through the top flues, and burn out the back end of fire, especially in a long fire-box.



NO STEAM WILL ESCAPE IF BROKEN OFF AT E OR F



WATER GAUGE GLASS.

FIG. 4.

There is also used what is called a petticoat-pipe, to fill the purpose of a diaphragm. This is made separately, and can be raised and lowered to regulate the draught.

The exhaust-nozzles *Z* are the outlet of the exhaust-steam from cylinders, and create a vacuum in the front end or smoke-arch, which causes a draught on the fire by the air rushing through the gates and fire to fill up the vacuum in the front end.

Fig. 1 represents an extended smoke-arch. The extension is for the purpose of catching cinders and sparks. The cinders are prevented from getting out of the stack by netting, Fig. 1, *N*. This netting is extended across the smoke-arch, so that the sparks and cinders strike the netting and fall back into the extension.

QUESTIONS.

How does the steam get from the boiler to the steam-pipe?

Through the throttle-valve into steam or dry pipe, to steam-pipe in front end and steam-passage in saddle.

What is the form of the throttle-valve?

It is a double disk-valve, and nearly balanced.

Why is it nearly balanced, and which disk is the larger?

It is balanced in order to be easily opened, and the top disk is the larger.

For what purpose is the dome, and where is it placed?

The steam dome is the highest point on the boiler holding steam, and is so placed to hold dry steam.

Where is it placed?

In wagon-top boiler, over the fire-box, as in Fig. 1.

For what purpose is the steam-pipe in boiler?

To carry dry steam from dome to steam-chests.

What is a crown-bar?

A bar over the crown-sheet, with its end supported on the side sheet of fire-box.

For what purpose is it used?

To support the crown-sheet, as in Fig. 1.

What is the water-line in a boiler?

The line on the top of the water in boiler which varies with the height and level of water in the boiler.

What is the effect of low water in a boiler?

Low water is dangerous, and it is liable to burn the sheets or flues if the water is too low.

How is it known how much water there is in a boiler?

By trying the gauge-cocks.

What causes the water to rise when the throttle is open?

The pressure is released on the water-line, and the heat causes the water to expand.

What causes a boiler to foam?

Impurities in the water, such as oil, soap, salt, and vegetable matter.

How is it known when a boiler is foaming?

By the sudden increase of the water in the boiler. If it is foaming badly, it is also shown by the appearance of foamy water at stack.

If a boiler had four gauges of water when the throttle was open, how many would be in it when the throttle was closed?

If foaming badly, water would probably be found in the bottom gauge.

How could the water be found in the boiler if water dropped below the bottom gauge-cock?

By opening the throttle suddenly or by blowing the whistle.

Should more water be put in the boiler if water thus appeared?

It should.

What should be done to prevent water from foaming after finding it?

The injectors should be put on and the boiler filled up, then the surface-cock opened and the impure water blown out of the boiler.

What is a water-gauge glass?

A glass tube on the back of the boiler for indicating the level or amount of water in the boiler.

If the water-glass should break, what should be done?

All water-glasses are supposed to have automatic-closing valves, so that when a glass breaks the pressure will close them; but if they should not, it would be best to shut the hand-valves.

If an engineer is running along and he finds that the water in the glass does not fluctuate, what is supposed to be the matter?

That the valves are closed or clogged up.

What should be done to make the glass indicate correctly?

Open blow-off valve and blow the water out of the glass, and see that the steam and water valves are open.

What is priming in a boiler, and what causes it?

Priming is entrained water in the steam, and carried over into the cylinder. It is caused by too great a quantity in boiler, or too small steam space and dome. It may also be caused by working the engine too hard.

What effect has priming on the working of the engine?

It reduces the power of the engine, by reducing the expansive power of the steam with which it mingles; and is wasteful, because it carries off heat that does no work in the cylinder. It is also injurious to the valves and seat by destroying lubrication.

Which is the more powerful, dry or wet steam?

Dry steam.

ACCIDENTS TO BOILER AND ATTACHMENTS.

When a throttle-valve becomes disconnected and remains open, what should be done to get train under control?

The reverse-lever should be put in the centre notch of quadrant, the steam-pressure reduced, and the train controlled by the air-brakes.

When the whistle-valve is broken, what should be done?

The whistle-bell should be filled with waste or any material to prevent the whistle from sounding. The engine can be run in this manner. Calculation must be made for the extra amount of water blown away free in steam.

When the whistle-stem is broken off, what should be done?

In this case the fire must be put out, as the escape of steam would be too great; but care must be taken that the water must not leave the crown-sheet before the fire is out.

Could the injectors be put on to maintain the water in boiler while fire is being knocked out?

Yes, if put on immediately. Good judgment must be used in cases of this kind.

When a wreck occurs and the engine has studs pulled out, or boiler-check broken out, what should be done to prevent burning the boiler?

If possible to get at the engine, and escaping steam would not interfere, the fire should be covered with sand, sod, or anything to dampen the fire, and then water put on if procurable. Do not undertake to put water on first, as it will be liable to burn the person so doing, as the steam and gas will rush out the fire-door.

When a blow-off cock is cracked or broken off, what should be done, and should the injector be put on?

The fire should be gotten out of the box if possible. In regard to the injector being put on, it would depend on the size of opening and the amount of water in boiler, or if the fire could be gotten out before the water left the crown-sheet. If the injectors would put water in the boiler faster than it was escaping, it would be policy to put them on, or if water is on the crown-sheet.

In cases when the fire must be knocked out of fire-box, and the engine is standing where any live coals would set fire to the material underneath the engine, what should be done?

The ash-pan dampers must be closed. (This applies to bridges and trestles also.)

Is it possible to bulge or drop a crown without it being burned?

Yes, it is possible, and is due to poor material in the crown stay-bolts, or a pressure in excess of the strength of material. In a case of this kind the fire is put out on account of the water rushing into the fire-box. The same occurs when a flue bursts. In either case the engineer and fireman are in immediate danger.

When the throttle becomes disconnected and closes how can steam be gotten into the cylinders to move it?

By the tallow-pipe valve.

In case of a dry-pipe bursting, what should be done?

The reverse-lever should be put in the centre notch, and the steam-pressure reduced. Control the engine by the brakes. If wheels should slip, do not use sand, as there is a possibility of making a wreck of the engine.

CHAPTER II.

FRONT END, OR SMOKE-ARCH.

THE steam-pipes in smoke-arch are connected to the end of steam or dry-pipe, which is called bulkhead or tee pipe, and joined to steam-passage in saddle, as in Fig. 5. The pipes have ball-joints, so that they may contract or expand (Fig. 6) as they are subject to varying temperatures.

Some builders use a ball and flat-ring joint, forming a rotating and sliding joint. The steam-pipes are fastened to the saddle or bed-casting, on shoulders or joints on the saddle, by studs.

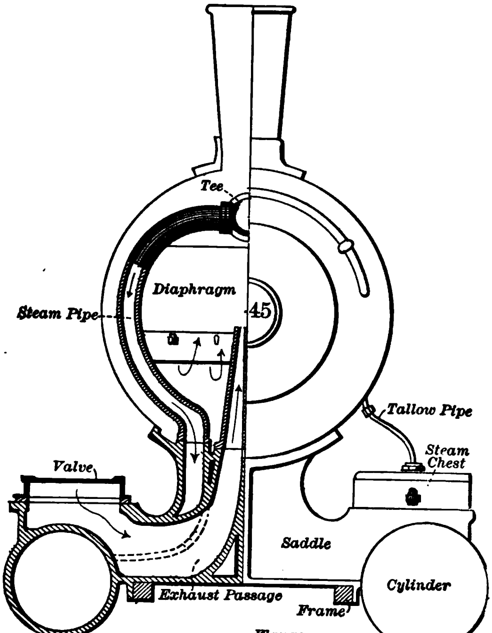
These studs become corroded in time, and are very difficult to get out, especially when the engine is warm. The reader will keep this in mind for future purpose.

The exhaust-pipes (Fig. 5) are the double exhaust-nozzle, or an exhaust-nozzle for each cylinder. The single exhaust-pipe is used on some roads with good results.

The engineer and fireman will frequently find that the engine, after steaming excellently for a while, will suddenly commence to steam poorly, and it puzzles them to understand it.

The difficulty is often found in the front end or smoke-arch, and is frequently caused by a loose exhaust pipe, causing back draught and impairing the vacuum in the front end. Sometimes the steam-pipe joints are leaking, which produces the same effect as a loose exhaust-pipe. Another cause is a loose diaphragm, which, having dropped down, spoils the draught on the fire. Other defects are a loose thimble on the end of the exhaust-pipe, and cinder cap off of the hopper or side of the extension. Another great

FIG. 5.



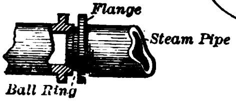


FIG. 6.

misfortune is the burning or warping of the extension, which is caused by the extension being filled with live cinders, while there is an air-hole or crack, into which the air rushes and comes in contact with the so-called cinder (which is in reality good coke), which has been drawn through the flues from the fire-box. This causes an intense heat around the air-hole, and burns the iron. Sometimes it is caused by the front door and frame being cracked, or the clamps loosened, or the door partly opened. Care should be taken that these are tight, and also that the front end should be cleaned out when full, as it interferes with the draught by covering up the front end of flues. Do not, however, do this while running, as it will blow back among the machinery and produce a very bad effect, and cause the parts to be cut and run warm.

QUESTIONS.

How are the steam-pipes fastened to the dry or steam pipe in the front end?

By being bolted to the bulkhead or tee.

What provision is made for contraction and expansion?

The joints have ball rings having a round and flat face fitting between the joint of the two pipes, as in Fig. 6.

What is the effect if the steam-pipe or the exhaust-pipe leaks?

It destroys the draught, and causes the engine to steam poorly.

For what is a diaphragm used?

To regulate the draught on fire and through flues.

How is the draught regulated by the diaphragm?

By raising or lowering the movable portion.

What is the effect of an air-hole, cracks, or a door partly open, on an engine having an extension, when full of cinders?

Will burn front end, crack door-frame, and spoil the appearance of the engine.

CHAPTER III.

STEAM-CYLINDERS AND CONNECTION.

LOCOMOTIVE steam-cylinders are made from the best cylinder iron, which should be hard and free from blowholes, but not too hard to be turned and bored out, and capable of having smooth cylinder walls in contact with the piston-head.

The cylinders are cast separately, in American practice, and bolted together, and are so constructed as to be neither rights nor lefts. There are three parts or names to a cylinder-casting, viz., cylinder, steam-chest, and saddle.

In the steam-chest, which is on the top of the cylinder, is the main steam-valve, which controls the inlet and outlet of the steam from the cylinder; and on the valve-seat proper, in most locomotives, is a loose or adjustable seat, capable of being renewed when worn out, without doing away with the cylinder.

Some engines have the seat cast with the cylinder, and when worn down have the false-seat attached.

In the steam-chest are five steam-ports, as will be seen in Fig. 7. 1 and 5 are the receiving-ports or openings of the steam-passages in the steam-chest. The steam-passage is divided. The passage or core, beginningat *B* in Fig. 7, passes down on the top of exhaust-passage and branches on each side of the exhaust core or passage, the walls of exhaust passage serving for both.

There seems to be a serious objection to this, from the fact of the difference in temperature of the steam in steam-passage and the exhaust-steam in the exhaust-passage, as it causes an unequal contraction and expansion, which often cracks the saddle, and also robs the steam of some degrees of heat.

FIG. 7.

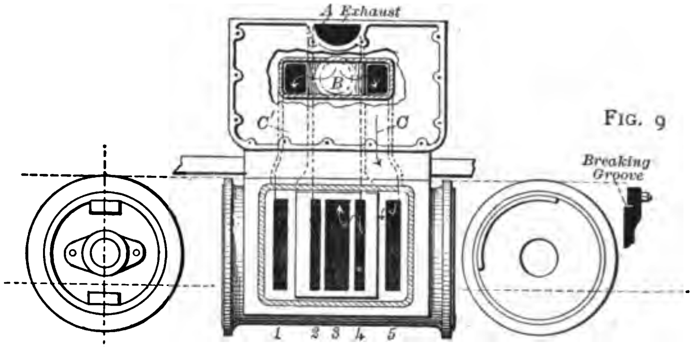


FIG. 9

Back Head outside view

FIG. 8.

Front Head inside view

FIG. 10.

Port 3 is the exhaust-port leading to the exhaust passages or core *A*, and leads the exhaust-steam from the cylinder to exhaust-pipe: so there are three passages or cores in the saddle.

Ports 2 and 4 are the steam-ports from steam-chest to cylinder, and through these ports all the steam passes that moves our trains over the roads. The steam passes out the same port after expanding and doing its work in the cylinder, which is governed by the valve.

Fig. 7 is a top view of the cylinder, valve-seat, and ports, also steam-chest and top of saddle. The flange on saddle has the same radius as smoke-arch, and is fastened to the same by bolts.

The cylinder is bolted fast to a frame, through a flange which is cast on the cylinder and the centre of frame. Also, there is a key or wedge on the sides of the saddle, to take up any lost motion of the saddles.

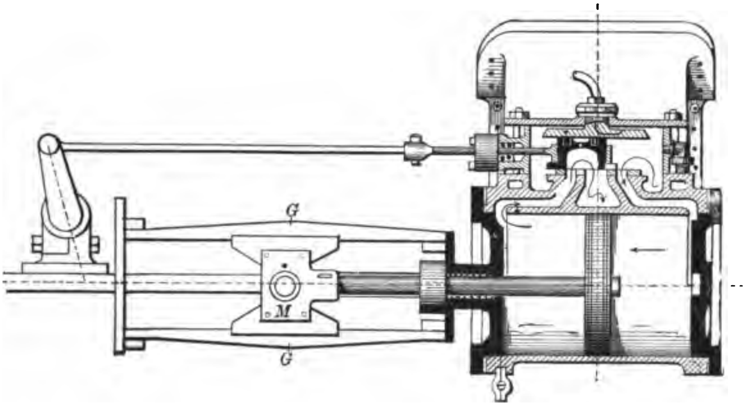


FIG. 11.

Fig. 11 is a longitudinal sectional view of a cylinder, piston-head, steam-ports, steam-chest, and valve. Fig. 7 shows only the top view of the steam-ports. Fig. 11 shows plainly how the steam-ports are. As will be seen, the core or ports are nearly a right and left angle, running from the seat into cylinders at each end. There is a shell or wall left between the bore of cylinder and port, of sufficient thickness for wear and reboring.

The exhaust-port is between the two steam-ports, That portion of metal between the ports is called a bridge.

On the valve-seat, and working over these ports, is a steam-valve, which is a hollow shell having flanges around it, and is frequently called a D-valve, being of the shape of the letter D.

In most engines of the present day the valves are balanced as nearly as possible. The object is to take as much pressure off the back of the valve as possible, in order to reduce the amount of power required to move valve, and also to prevent the excessive wear of valve and seat, so as to be easily handled by the engineer.

The most common method of balancing is by putting bars on the back of valve, as in the Richardson valve, having a balance-plate fastened to steam-chest cover, as in Fig. 11.

The bars have under them in grooves on the back of valve springs which force the bars up against the plate, making a steam-tight joint, or nearly so, and thus reducing the area of valve which is exposed to the downward pressure of the steam.

There is a small hole in the centre of the valve, which releases the valve from any pressure that might be caused by steam getting past the bars. This hole opens into the exhaust cavity.

By referring to Fig. 11, you will see that the forward steam-port is wide open, and steam is passing into cylinder against the piston-head.

The exhaust-cavity of the valve is over the back of steam-port, and the exhaust-steam is passing out of the port into the cavity of the valve, into exhaust-port.

This action takes place for each end of the cylinder. The valve is encircled by a yoke, which has a stem passing out of steam-chest, through suitable packing.

The valve is free in yoke, so as to adjust itself to the wear.

The piston-head is an important factor in a locomotive, and without it we could not handle our trains as we do, as there is nothing yet constructed that can take the place of a piston-head, and with as little complication. What is essential in a locomotive is a smooth-working, steam-tight piston. The power of the engine principally depends on the area of the piston-head in square inches, as the larger the piston-head the greater the power of the steam-pressure.

The most common method of making a piston-head tight is by cutting grooves in head, and springing cast-iron rings into the grooves, whose diameter is larger than the bore of the cylinder; then when put in the rings are compressed, and fit tightly against the walls of the cylinder. But when the rings become worn, they spread open where they have been cut, and the steam blows through, which creates a loss of heat and power, which is not economical.

There are devices to prevent this, such as dowel-pins and lap-joints. Dowel-pins have a tendency to wear grooves in cylinder and let the steam blow through. Lap-joints or tongues break off and produce the same result. There is also danger of knocking out a cylinder-head and doing other damage by means of broken tongues.

A simple device, which has demonstrated itself to be a perfect remedy for this joint, and which is easily constructed, is shown in Fig. 12. It is called a break-joint block, and is in the form of a T, or a block having a tongue. This block is put in a groove back of ring groove of piston, and of the same depth and width. The tongue extends into ring groove, between ends of rings.

This block should be carried on the bottom of the cylinder.

The operation is as follows: The steam-pressure drives the ends of rings against the block, making it the same as a solid ring, and the tongue prevents the ends of ring from turning around on the top. The block wears with the rings, due to gravity. This device recommends itself on account of its simplicity and absence of springs or pins, and the results obtained from it after severe trials in all classes of locomotive service.

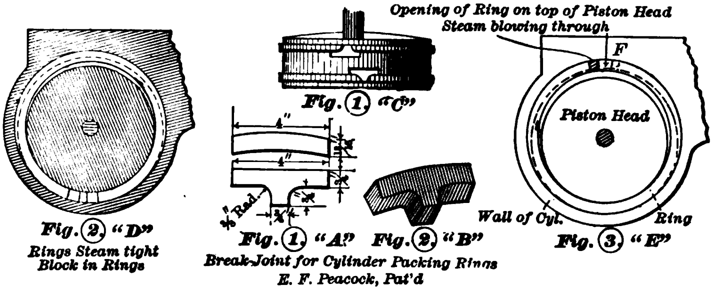


Fig. ② "D"
Rings Steam tight
Block in Rings

Fig. ① "C"

Fig. ① "A" Fig. ② "B"
Break-Joint for Cylinder Packing Rings
E. F. Peacock, Pat'd

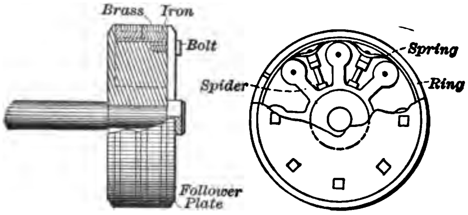
Fig. ③ "E"

FIG. 12.

We have another method of packing, in which the piston-head is made in sections (Fig. 13). This packing requires to be set out by the engineer when worn.

The forward portion is called the spider. Between the arms are screw-studs, and on these are steel springs, which bear against the wide or bull ring. On this ring are the two packing-rings, which are cut and bear out against the cylinder walls, due to the pressure of the springs on studs.

The front plate is called the follower-plate, and is bolted fast to the spider. This form of packing is more expensive than the spring ring, and has some defects, namely, that of being set out too tightly, which causes excessive friction and wear of cylinder, and also that the packing will sometimes fall and become follower-bound. Figs. 8 and 10 show the front and back cylinder-head.



Piston Head
Fig. 13.

As will be seen, there is a groove cut in head at *B* in order to prevent breaking off the face of the cylinder when a head is broken out. Attached to the piston-head is the piston-rod.

This rod passes through the stuffing-box in cylinder-head, and is fastened in the sleeve of cross-head. Fig. 11 shows the cross-head, which is of the vertical or two-bar type of cross-head, by some called the alligator cross-head.

This cross-head consists of three parts, the main body

(*M*), and the top and bottom shoe. This combination acts as a carrier for the back end of piston-rod. To the centre or wrist pin is attached the main rod, which is not shown in Fig. 11.

The shoes are made separate from the main portion of the cross-head, so that they can be taken off and relined or babbitted; and if a shoe breaks, it can be replaced without throwing away the whole head. This cross-head slides between the two guide-bars, as in *G G* in Fig. 11. These bars are fastened to the disks on stuffing-box, on the front end, and to a yoke at the back end. The most wear occurs on the top guide-bar and shoe.

Some of our students may wonder as to the cause of this wear on the top guide in forward motion, and why it is more on the bottom guide in the backward motion. It is caused in this manner: In taking the back stroke, the pressure against the piston-head is pushing back the crank-pin, which is on the bottom quarter, the resistance is at pin below the centre-line of motion, through the piston-head, and there being a joint between the power (piston-head) and the resistance (crank-pin) causes the cross-head to be pushed up against the guide-

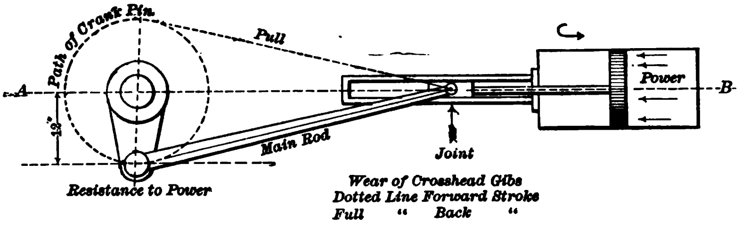


FIG. 14.

bar, as in Fig. 14. In the forward stroke (forward motion) the cross-head is pulled up against the guide-bar, as in Fig. 14.

In the backward motion this is reversed, and the wear is greater on the bottom guide-bar. This should be thoroughly understood by an engineer, as it will frequently aid him when he breaks a cross-head or shoe.

There is the four-bar type or horizontal cross-head, to which these remarks also apply.

QUESTIONS.

How are the steam-cylinders made in American practice?

They are cast separately, and bolted together.

Name the three parts of a cylinder.

Cylinder, steam-chest, and saddle.

Are there right and left hand cylinders?

No, the cylinders are used for either side.

Why can this be done?

Because the ports are in the same position when used on either side and the exhaust and steam passages are in the centre of the saddle, and the cylinder heads fit on either end of cylinder.

How does the steam get from the steam-pipe to the steam-chest?

Through the steam passage or core in the saddle, as in Fig. 7, *B*, which shows the passage on each side of the exhaust-passage, and from there through receiving ports, shown by 1, 5.

How many ports in the steam-chest?

Five. Two receiving-ports, two steam-ports, and one exhaust-port.

For what purpose is the exhaust-port?

To let the steam that has expanded in the cylinder pass out into the exhaust-passage, as in Fig. 11.

For what purpose are the steam-ports?

Passages or ports to let the steam into cylinder from the steam-chest.

Does the steam pass out the same port that it goes in?

It does.

What is the metal between the ports called?

Bridges.

What controls the inlet and outlet of the steam from the cylinder?

A valve.

What is the shape of the valve?

It is in the form of the letter D, having a cavity in the centre, which is called the exhaust-cavity, as in Fig. 11.

On what does the valve slide?

On a seat.

What is a balanced valve?

A valve having almost all the pressure taken off the back.

How is this done?

The most common method is by putting strips or bars in grooves on the back of the valve, and having a plate above the valve fastened to steam-chest cover, against which the bars slide, making a steam-tight joint, or nearly so, and thus reducing the area of valve which is subject to the downward pressure of the steam. (See Fig. 11.)

What provision is made for the steam that might leak past the bars?

A hole is bored through the top of the valve into the exhaust-cavity, thus taking off any pressure that might accumulate.

What is the advantage of a balanced valve?

It reduces the friction and wear of valve on seat, and requires less power to move the valve, and makes the reverse-lever easy to handle.

What surrounds the valve?

A yoke having stem passing out through stuffing box (Fig. 11).

What and where is the piston-head?

It is a round disk, against which the steam exerts its pressure. It slides in the cylinder.

How is the power of an engine increased with a given steam-pressure.

By increasing the size of the piston-head.

How is a piston-head made tight?

Most piston-heads have cast-iron spring rings fitted in grooves in head, which spring out against the cylinder walls.

Do they ever leak?

They frequently leak when worn where cut, if nothing has been provided to stop the leak.

What is the result if they leak?

Loss of power and waste of force, as the live steam blows out the stack.

Can they be made steam-tight without complication?

They can. (See Fig. 12.)

What is the use of the cross-head, and what is attached to it?

It acts as a carrier for back end of piston-rod and also for front end of main rod. The piston-rod and main rod are attached to it.

Between what does it slide?

Between the guide-bars.

Which guide is more worn in the forward motion?

The top guide-bar.

Why is this?

When on back stroke the crank-pin is below the centre-line of motion, and the push of the piston drives the cross-head against top guide; on the forward stroke the crank-pin is above the centre-line of motion and the pull of piston draws cross-head against top guide-bar, the joint being at the wrist-pin in both cases, when running backward the wear is greater on bottom guide-bar. (See Fig. 14.)

Explain the course of the steam in Fig. 11 by the arrows.

As shown, the forward port is fully open, and steam is passing in the front end of the cylinder against piston-head. The steam from back end of cylinder is passing out port under valve, into exhaust-port.

Breaking-down will next take our attention; and as it is essential that the engineer or fireman should thoroughly understand the construction and principle of his machine, we have endeavored to make it clear so far as we have gone. He should also understand how to disconnect his engine when broken down, and how to clear the road.

There is one point the reader will do well to remember, that whenever a breakdown occurs which requires the cylinder on the broken side to be run without steam in it, the piston-head must be without motion, or disconnected, and the steam-ports to be covered in all cases except in towing, as a dead engine.

The writer will try and illustrate the method of disconnecting, so as to make it plainer to the student; and he holds the theory that an illustration of the break and repair can be remembered for a longer time than if told in so many words.

QUESTIONS ON BREAKDOWN AND DISCONNECTING.

When a cylinder-head is knocked out by a broken piston-rod, what should be done?

If the piston-head went clear of cylinder without breaking anything but the head, the best plan is to place valve in the centre of seat and clamp valve-stem. If there were no clamp at command, tie valve-rod up to hand-railing with a rope. In all cases disconnect valve-rod from upper rocker-arm, but do not take down the main rod. Position of valve is illustrated by Fig. 15.

What must be done if a valve-rod breaks?

Do the same as in the breaking of a cylinder-head, except that in this case the main rod must be disconnected from the cross-head. This is shown in Fig. 15.

Why must the main rod be disconnected in this case, and not in breaking out the head, the piston going out to clear?

Because in that case there was no piston in cylinder to cut, and in the other there is; so the main rod must be taken down to prevent cutting the cylinder.

If you were near a siding, would you disconnect the main rod on broken side?

Not unless the distance were very great. It is better to clear the main line as soon as possible.

In what position should a cross-head be blocked?

In the back end of guides. (See Fig. 15.)

Why should it be blocked in the back end of guides?

Because when blocked in the front end, if the steam should get in front of the piston-head, and blocking should slip or break, it would be likely to knock out backhead, bend the guide-bars and yoke, and also injure the packing. If blocked back, it would knock out front head only.

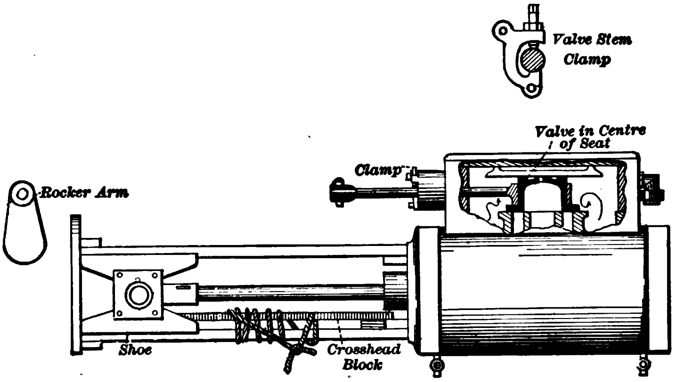


FIG. 15.

Why would it not break out backhead?

Because the piston-head would strike the front head, and the force of the blow would be reduced before the cross-head would strike the backhead. This is the case where the main rod breaks.

When a valve-stem breaks, what must be done?

Clamp valve-stem, having the valve covering the ports. Take down main rod, block cross-head, and disconnect valve-rod from rocker-arm, as in Fig. 15. This applies to broken valve-rod.

How can a broken valve-yoke be found without taking off steam-chest cover?

Place the engine on a quarter on the side supposed to be broken, open cylinder-cocks, give the cylinder a little steam, and pull reverse-lever back and forth. If steam comes out of cylinder-cock only, it would show that the break was on that side.

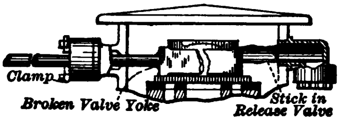
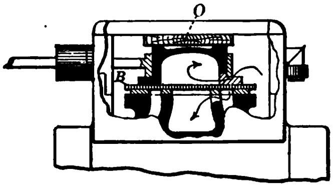


FIG. 16.



Broken Valve or Bridge
B—Board between Valve and Seat
O

FIG. 17.

Why should the engine be put on a quarter?

In order to have a full travel of valve over seat.

After finding broken yoke, how should the engine be disconnected?

In the same way as in the case of broken valve-rod, except that in this case the release-valve should be taken out. Cut a stick and put in release-valve* nut, with the stick against steam-valve so as to hold valve central over ports, as in illustration, Fig. 16.

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* Also called *relief-valve*.

What should be done in the case of a broken valve or bridge?

Put a board over the valve-seat, put valve on it, bolt steam-chest cover down on it. This is in an engine where a balance-valve is not used, as in Fig. 17.*

If both cylinder-heads broke out, would it be possible to run the engine?

Yes, by blocking up the front steam-ports, and running with the back-ports.

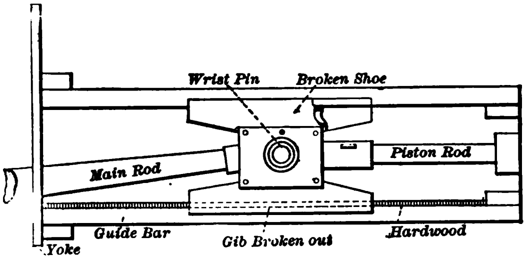

FIG. 19.

When a release-valve blows out, what must be done?

Put a wooden plug in the hole, if thread is not stripped.

If a piece broke out of steam-chest, how could steam be prevented from entering the steam-chest?

By putting a blind-washer in steam-pipe joint.

Could this be done very easily?

It could not, on account of the heat from the fire; and in most cases where the engine has run for any length of time the studs are corroded, and hard to get loosened.

When a cross-head shoe is broken, what should be done?

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* A block of wood can be substituted for the valve when balance-plate is used.

If not broken too badly, and especially the bottom one, the engine can be run. If the top one is broken, however, it must not be over half gone. When running forward also in case a gib breaks out entirely, a board of the thickness of the gib should be put on the guide-bar. (See Fig. 19.)

Remember that you should always block the valve in centre of the seat. Cover the ports. Do not shove valve ahead or back, leaving one port open. This is a bad practice.

CHAPTER IV.

LOCOMOTIVE FRAMES, DRIVING-BOXES, AND SPRING RIGGING.

LOCOMOTIVE frames, as used in American practice, are of the bar type. On most foreign roads they use the slab and compound frame. The bar frame seems best adapted to our locomotives.

The frame is a very important part of an engine, as it must take all the thrust due to the push and pull of the piston, and the resistance in the weight of the train behind. It also keeps the driving-wheels in their respective places, carries the boiler, cylinder, and all the machinery connected with the boiler.

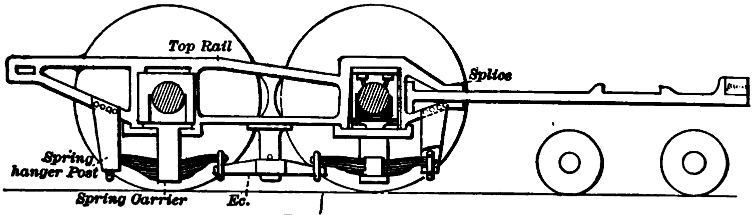
This in turn is carried by the driving-axles, so it is plain that the locomotive frame must be well made.

The construction of the bar type is as follows: In an eight-wheel or passenger engine, as shown in Fig. 20, it is composed of two parts—the back portion, which contains the pedestals or jaws for the driving-boxes, and the forward portion, which carries the cylinders and rocker-arms and tumbling-shaft.

As will be seen in Fig. 20, the top rail of back part of frame is dropped behind the front driving-box. This is for the purpose of getting a deep fire-box or slope in the front end. In this form of frame the fire-box is above the frame, thus getting a wider fire-box than could be done if the fire-box was between the frames.

The pedestal-jaws or frame-legs are forged to the top and bottom rails, thus binding the two rails together. In some engines they are forged only to the top rail, and the bottom rail is bolted to jaws. Fig. 20 shows solid frame.

The forward portion or bar has a T head and the bar is between the two rails of the back part, which are drawn together, binding the forward part.



Passenger Engine 8 Wheel
Spring rigging underneath frame

FIG. 20.

The T head or bar is bolted to jaw, and the whole is called the splice. On the forward part of bar are two shoulders, between which the saddles are bolted.

There is a key at this point to take up any movement of cylinder. At the extreme end comes the breast-beam, to which is bolted the pilot.

Fig. 21 shows a consolidation engine for heavy freight service. As will be seen, there is no splice in this frame, and there are four pedestal-jaws.

In this engine all but a small portion of the entire weight of the engine is carried on the driving-wheels.

The forward end of the frame is brought together in order to clear the pony-wheel.

On the bottom of pedestal jaws are bars or binders, which are bolted to the bottom of jaws, and are usually called pedestal-caps. These are for the purpose of making it possible to take out the driving-boxes, or dropping out wheels, which could not be done if they were solid, unless the end of axle and wheel were loose. They also serve to bind the jaws together.

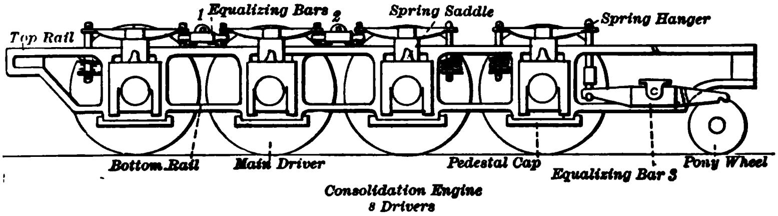


FIG. 21.

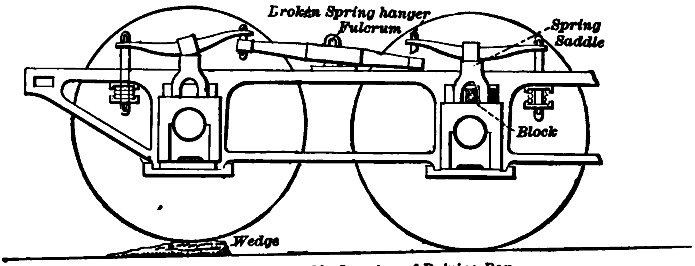
The number of jaws and style of frame is governed mostly by the number of driving-wheels.

In order to make an engine ride easily and reduce the shocks and concussion on the running gear, the engine is provided with springs which are called driving-springs and engine-truck springs.

The driving-springs are placed over each driving-box and carried on a saddle which straddles the frame, resting on the top of the driving-box in the most common form of construction, as in Fig. 21, which shows the construction very plainly.

Fig. 20 shows a different method of placing the springs. In this form the spring rigging is underneath the frame. By referring to Fig. 20 you will see that the springs are supported by carriers whose upper ends have an eye in them, and a pin runs through the flanges of driving-boxes and the eye of carrier, thus making a support for the driving-spring.

The driving-box takes the weight, as in other forms. In order to equalize the weight between the drivers, there are provided bars, which are called equalizing-bars. These are placed between the drivers, on the top of the frame, in the form using springs on top, as in Fig. 22. Fastened to the frame are fulcrum-posts. The bar has an eye in it into which the post fits. Passing through the post is a pin, forming the fulcrum or axis on which the bar rotates.



Wheel Run up on Wedge to block on top of Driving-Box.

For {
Broken Spring hanger
" *Equalizing Bar*
" *Spring*
" *Saddle.*
" *Tire*

FIG. 22.

The ends of the bar are attached to the springs by a spring hanger. If equalizing-bars were not used, the weight would not be distributed evenly on the drivers, for an illustration, if we should place the frames down on the top of the boxes, and run over an uneven piece of track, the weight would be taken one time by one driving-box and then by the other. This is from the fact that the one in the hollow place would drop away from the frame and leave all the weight on the one on the highest part of the rail, and this action would take place also when the other wheel dropped into the hollow or low place.

This happens when passing over switches; but in using the equalizing-bar, whose ends are fastened to the springs over each driving-box, and having an axis around which it can rotate, the weight being concentrated at that point, either of the drivers can go up or down, but the weight will be carried by both driving-boxes, because the bar can adjust itself to the movement of the boxes on either side of the axis.

In Fig. 20 the equalizing-bar is underneath the frame, for the purpose of getting the fire-box on top of the frame.

In Fig. 21 you will see that three pairs of drivers are equalized together, but the front pair is connected to the pony-truck by equalizing-bar, thus equalizing front driver and truck.

There are coil springs on the end of spring hangers. The forward equalizing-bar is bolted to the under side of the saddles or bed-casting.

Driving-boxes are generally made with a shell of brass, but in most modern locomotives the driving-box is cast solid, of some good composition, such as phosphor bronze.

The advantage of a cast-steel box with a shell over a solid box is that the shell can be renewed without disposing of the whole box, as is done when a solid box wear out.

Driving-boxes are set in the frames or pedestal-jaws, and between them and the jaws are two pieces of metal, front and back. That in the front is called the shoe, and it is perfectly straight. The one back is called the wedge, and is tapered; the jaw is also tapered. This is done for the purpose of taking up the wear due to the push and pull of the piston. The wedge must not be too tight or the frame cannot oscillate up and down; or if the driving-box becomes a little warm, the wedge and frame will stick, which causes the engine to ride very hard on the driving-boxes. As will be seen by Fig. 23, the wedge has an arrangement at the bottom to adjust it, which is called a wedge-bolt. The one shown is the standard on the P. R. R.

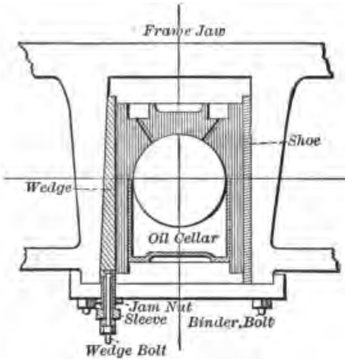


FIG. 23.

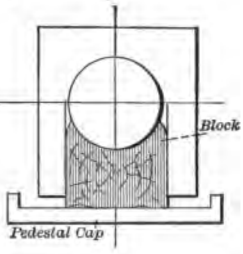


FIG. 24.

There is a hollow bolt having a head on the lower end, and the body threaded its entire length. The pedestal-cap or binder is also threaded. This hollow bolt screws into the cap and abuts against the bottom of the wedge. In the centre of this hollow bolt is the wedge-bolt proper, the upper end of which has a head which fits into the wedge. On the lower end are two nuts for jamming to hollow bolt. To set the wedge up you first unscrew the nuts on wedge-bolt proper, then screw the hollow bolt up; this carries the wedge with it. When raised far enough, screw the nuts up on the wedge-bolt against the end of hollow bolt. This binds the wedge fast to the hollow bolt, using a jamb-nut on the hollow bolt to bind it to the pedestal-cap.

To lower, do as in raising, except to draw the hollow bolt down, and screw up nuts against hollow nut, and that will draw the wedge down on the top of hollow bolt.

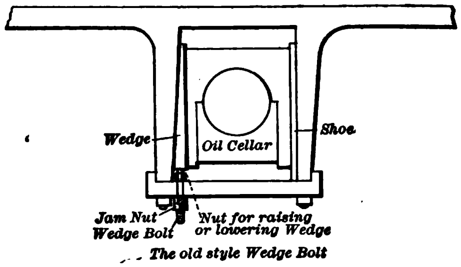


FIG. 25.

To keep the driving-boxes thoroughly lubricated, there is an oil-cellar fastened between the flanges of the driving-box, which is hollow, and fits closely to the axle. This is filled full of waste suitable for packing cellars, and well oiled or sponged up.

The tops of driving-boxes have oil cavities with oil-holes leading to journal. Sponging is put into the cavities in the top. The cellar catches the oil that passes around the journal and underneath it. The sponging must bear against the under side of the journal, or the box will become hot and give trouble. When the sponging becomes hard, due to being burned, it should be taken out and fresh sponging put in, as when hard it drops away from journal, and the capillary action is also stopped.

Setting up wedges is something that should be understood by all engineers. The proper position to place an engine is on a straight, level piece of track; then place the crank pins on the side you are working at on the top quarter, in the forward stroke, put a chock under wheels, and give the cylinder a little steam. The idea of this is to take up all the lost motion between the driving-box and shoe, for in this position the piston pulls box to shoe, and the cylinder-head pushes frame against box, leaving the wedge free. The engineer must use his own judgment as to how far the wedge must go up. To use finer adjustment, you must slack up the keys on the rods, and key up after setting up wedges. (See Fig. 26).

Breaking down any portion of spring rigging sometimes presents a difficult problem, as all engines are supposed to carry jacks, but do not do so. Then the question of how to raise the weight is solved by using a wedge of wood or iron, as in Fig. 22, which shows a broken spring hanger which has let the frame down on the driver, and the end of equalizer down on the frame. The best thing to be done in this case is to put a wedge under the wheel, either back or front of the one with the broken hanger, and run this wheel up on wedge. This will raise the frame off the driver with the broken spring; then put on top of the box a block or anything that can be put in between frame and box, such as a piece of fish-plate; then run the wheel down off the wedge, and put a block undert he low end of equalizer. In order to do this, run the wheel that is blocked up on a wedge, and this will take all the weight off the bar; then take down all loose parts, and proceed.

With the spring rigging underneath you do as in the former case; but to raise equalizing-bar it is best to put a wedge or roller under the low end of equalizing-bar

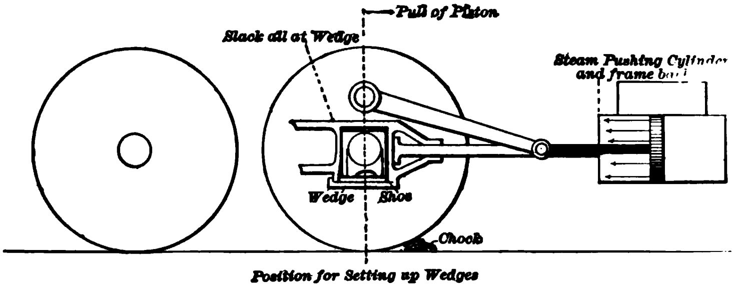


FIG. 26.

and move the engine back. If a front hanger, this will raise the bar, and then chain fast to frame. It is policy, when running a wheel up to raise frame, to put a block on top of that box, to take the strain off the springs, also to move frame more quickly; but leave it small enough to enable it to be taken out, when run down off wedge.

When a spring, spring hanger, equalizing-bar, or spring saddle breaks, do as in Fig. 22 (broken hanger), removing all loose parts. When a tire breaks, the wheel containing the break should be run up on a wedge as thick as the tire, then the oil-cellar should be taken out and a block of wood substituted, as in Fig. 24. This will carry the weight, and make a bearing for the axle to revolve on. Never let the axle revolve on the oil-cellar, as this will cut the axle and ruin it. When an axle is broken off outside the driving-box this would not be absolutely necessary, for that axle is spoiled but block between pedestal-cap and cellar and top of box and frame.

QUESTIONS.

Upon what does the boiler and cylinder rest?

The frame.

What takes the pull and push of piston and resistance of train?

The frame.

What names are applied to the different parts of the frame?

The top and bottom rail, pedestal-jaws, and splice.

What is the use of the pedestal-jaws?

To hold the drivers in position.

What is the splice?

It is that point in an eight-wheel frame that the forward portion or bar is attached to, the back part of frame in front of front driver.

What governs the number of jaws in a frame?

The number of drivers to be used.

For what is a pedestal-cap or binder used?

To permit wheels and boxes to be dropped out or put in; also to bind jaws together.

Why are springs used?

To make engine ride easily; also to avoid the concussion and jar, which would be hard on machinery and road-bed.

How is the weight on driving-boxes equalized?

By equalizing-bars attached to a frame and springs between driving-boxes, the weight suspended at the centre of bar or at the axis of rotation.

How will it equalize the weight between drivers?

If one driver goes up or down, the end of the equalizing-bar will go up or down with the box, and the weight will still be divided between the two boxes.

What is the result of using independent springs?

When one driver goes up or down, due to uneven track or frogs, it will throw most of the weight of engine on the high wheel, thus reducing the adhesive power of the low wheel, and making the engine ride hard.

What is a spring saddle?

A U-shaped iron spanning the frame and resting on the top of driving-box, upon which the springs rest.

What is a spring hanger?

An iron link connecting the spring and equalizing-bar, or spring and frame.

Of what materials are driving-boxes made?

Of cast steel and phosphor bronze. Cast-steel boxes have brass shells next to journals.

What advantage has this over a solid box?

The shell can be renewed without renewing the whole box.

What are wedges and shoes used for between boxes and jaws?

Shoes are used to prevent the wear of pedestal-jaws or frame-legs; wedges are used to take up the lost motion between boxes and pedestal-jaws.

On what side is the wedge in most locomotives?

On the back of the driving-box.

How is the wedge set up or pulled down and fastened?

By a wedge-bolt, as in Fig. 24.

What is an oil-cellar?

A hollow shell held between the flanges of driving-boxes, which is filled with sponging and oil to lubricate driving-box and journal.

What is the principal cause of driving-boxes getting hot?

The sponging dropping away from journals or getting hard.

In what position should your engine be placed to set up wedges?

On a straight, level piece of track, put crank-pin on top quarter in forward stroke, give a little steam in cylinder, and put a chock under wheels.

Why would you do this?

To get all the lost motion in the wedge side of box.

When a spring, spring hanger, or equalizing-bar or saddle breaks, what should be done?

Run wheel up on a wedge, back or front of wheel having a broken spring or hanger, and put block on top of that box, between box and frame, as in Fig. 22; run wheel down off wedge, and take down all loose parts. If equalizing-bar broke in centre, would put blocks on top of both driving-boxes, and proceed.

When a tire breaks, what should be done?

Wheel should be run up on a wedge the thickness of tire, the oil-cellar taken out, and a block put in as in Fig. 24.

Would you run without taking cellar out?

No, except when the axle breaks off outside of box, and then it is not absolutely necessary.

What is the difference between an engine-truck and a pony-truck?

An engine-truck has four wheels, while a pony-truck has only two. It is used in consolidation and mogul engines.

If an engine-truck wheel or axle breaks, what should be done?

If a forward wheel broke, collars should be set up close to boxes. Box and frame should be chained up to main frame, and a cross-piece put on back of truck frame between that and the main frame. Do the same with the back wheel. Proceed cautiously in all cases of this kind.

What should be done when a back or front driving-wheel or axle breaks on an engine?

The back or front wheels should be blocked to clear rails, and rods disconnected.

What is a blind wheel?

A wheel without a flange.

Which are the blind wheels on a consolidation engine?

The two middle drivers.

Why are these wheels made without flanges?

So that the engine will go around curves of short radius.

What is the blind wheel on a ten-wheel engine?

On a ten-wheel engine it is mostly the forward driver; in a six-wheel engine the blind wheel is the main driver or centre wheel.

CHAPTER V.

RODS AND CONNECTIONS.

THE main or connecting rod is the rod that connects the cross-head with the crank-pin, and transmits the power to the whole number of driving-wheels, and is therefore called the *main*-rod. This is illustrated in Fig. 27.

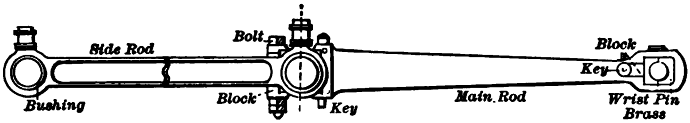
The main rod has brasses in each end, front and back. The front ends fits around the cross-head, or wrist-pin. The brass is in two pieces, and is set up by a key. Some rods are made solid, while others have straps. The P. R. R. standard for eight-wheel engines is as in Fig. 27. In driving this key (*B*) care must be taken that the set-screw (*S*) is loosened before starting key.

The back end of main-rod is the end that encircles the crank-pin. As with the front end, the rod is made with or without a strap. Fig. 27 shows a rod with a forked end, and the brass is slipped in from the back, while a block fits in between forks, and a large bolt passes through the forks and block, thus holding brasses in their place.

This is a convenient way of making rods, but there is this objection to it: If a strap or fork breaks, the whole rod is useless in that condition, and besides, it cannot be taken down on the forward centre. In other forms the rod has a strap bolted to the main portion of rod, and leaves what is called the stub end when the strap is taken off; and if the strap breaks, it may be renewed without rendering the rod unserviceable, and can be taken down in any position.

Side-rods or parallel-rods are the rods connecting the driving-wheels together. Many efforts have been made to get a substitute for these rods, but nothing has been devised that will do better.

Where only two driving-wheels are used there is only one section of rod on each side, as in Fig. 27.



Rods for an 8 Wheel Passenger Engine

FIG. 27.

This shows a fluted or I section-rod. This form is very desirable on account of its strength and resistance to centrifugal force. This rod has no keys or straps, but has bushings of brass in each end or eye of rod. This makes a very simple form of brass, but when worn badly it must be renewed as a whole, and cannot be reduced to fit the pin, as in brasses which are in two parts, with keys to adjust them to the pin.

To keep the bushing from turning, a stud is screwed down through the eye of rod and bushing, in which is screwed the oil-cup.

On freight engines using three, four, or five driving-wheels, as in Fig. 21, the side-rods are divided into sections, as in Fig. 28, showing a set of rods for a consol-

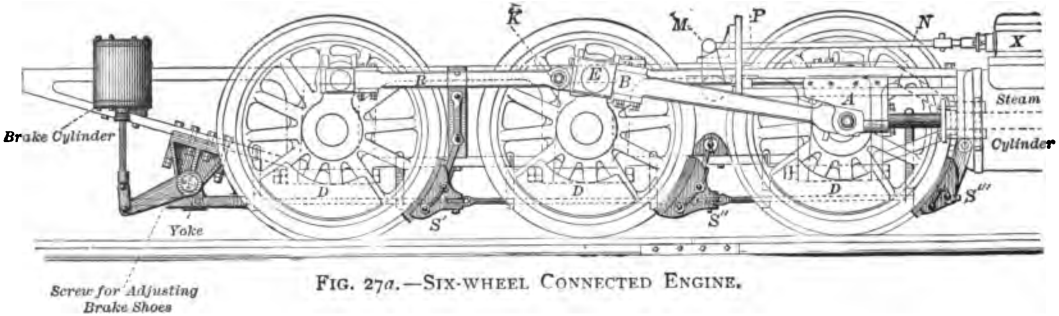


FIG. 27*a*.—SIX-WHEEL CONNECTED ENGINE.

N, Two-bar Guide.
P, Valve-rod.
D, Counter-balance.
X, Steam-chest.
M, Rocker-arm.
E, Main-pin.
B, Main-rod.
A, Cross-head.
R, Back-section Side-rod.
K, Knuckle-joint.
Main Driver without a Flange.
S', *S''*, *S'''*, Brake-shoe and Clogs.

idation engine. The main pin is on the third wheel from the front end. This set of rods is divided into three sections. The middle section is on pins 3 and 2. The straps on each end have an eye on their back ends. The other sections front and back, or 3 and 1, fit on their respective crank-pins. The ends of sections 1 and 3 have their ends next to pins 3 and 2 forked. These ends span the ends of the straps of the middle section, which have an eye in them. A pin passes through the two, binding them together, and forming what is called a knuckle-joint.

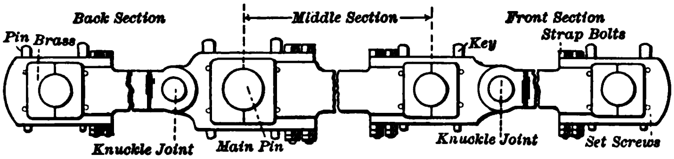
This joint is provided for unevenness of track, frogs, or going on a turntable. If this was not provided, and the rods solid, or if one wheel raised or lowered, it would break the rods.

Six-wheel connected engines have only one knuckle-joint, using two sections of rods. The joint is back of main-pin on most engines. On rods using straps there are keys or wedge-shaped pieces of steel, which pass through the strap, bearing against the brass and strap or strap and stub end of rod.

This is done in order to adjust the brasses to the wear by raising or lowering the keys. Most pin brasses have two keys, the one front and the other back; but some engines have only a single key on the main-pin brasses, on main-rod and side-rod. When made this way the key moves the front brass up to pin, and must pull the whole rod in order to get the back brass up to pin. This causes the rod to be lengthened, unless liners are put in between the brass and the back end of strap. In the back of main-rod brasses babbitt or other similar metal is placed in grooves, which prevents the brasses from heating so quickly as without it.

When a pin gets so warm that it commences to throw the metal out, it begins to give trouble to the runner, and if judgment is not used the pin will get worse and cut. It will be found in most cases that there is some obstruction in the oil-cup which prevents the oil from getting down to pin, and when the metal starts matters become worse, as the metal will fill up oil-way in cup solid.

Oil-cups are made with a regulator or needle in them, which can be lowered or raised to regulate oil flowing to pin, and it frequently happens that dirt or waste gets around the point of needle and stops the oil. This will cause heated bearings.



Consolidation Engine
Side Rods

FIG. 28.

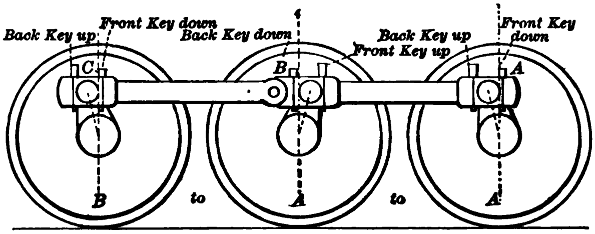
Cups should be kept clean; and in order to make the cup feed regularly, an engineer should take the cup off, fill it with oil, and set regulator by the drop, which he can see issuing from the cup if he holds it up to view.

Another cause of the rod-brasses getting warm is too tight keying, which binds the brasses to pin, and causes much friction. In this case keys should be slacked up, according to judgment. Again, the brasses will not fit the strap correctly, or the key will be driven down too hard, springing the crown of brass.

Every engineer should understand how to key up an engine, as it is one of the important parts of an examination for promotion by a travelling engineer or master mechanic.

When keying up the side-rod always place the crank-pins on the centre, either forward or back. By so doing the length of rod will not be changed, as the pins are in the centre-line of motion through wheels and cylinder, and this is also the extreme point of travel of pin through the centre-line of motion.

Never key rods up with the pins on top or bottom quarter, for the reason that then the rods can be lengthened or shortened, as in Fig. 29; which will be plain to all, as the pins are above the centre-line of motion, and form a lever with the axis of motion at the centre of the wheel. The pins can be drawn to or spread without moving the engine in a horizontal direction. Driving down the keys *A* and *B* would



Showing the effect of Keying Side Rods.
On the C. Quarter(Drawings Exaggerated)
A to A the Rod has been Shortened.
B " A " " " " Lengthened.

FIG. 29.

shorten rods, while driving down *C* and *B* would lengthen them. We see, then, that in either case when the pins come to the centre they would be either too long or too short, which would cause them to buckle or break if their length was changed greatly by keying.

The question with which brass to begin depends on the number of keys to a brass and the rods. On a six-wheel connected engine using a single key in front of pin it is policy to drive that key first, the others being slacked off, as this key must push brass up to pin and pull back brass to pin by moving the whole rod.

When keying up the front end of the main-rod it is a general rule to put crank-pin on either quarter, which brings the brass on the large part of pin, as the wear of wrist-pin is oblong, due to the push and pull, the pin remaining stationary, which causes the pin to be larger at top and bottom.

QUESTIONS.

What is the main-rod on a locomotive?

The rod connecting the cross-head with the crank-pin.

What are the side or parallel rods for?

To connect the drivers.

Are they solid rods throughout?

No; it depends on the class of engine, as those using but four driving-wheels have only a single rod. Six-wheel connected and consolidated engines have their side-rods divided into sections.

What is a knuckle-joint, and why is it provided?

A knuckle-joint is the point at which the sections are joined together, as in Fig. 28. This is provided so as to allow for variation in the height of the driving-wheels in passing over rough track, frogs, or turn-tables.

If there was no knuckle-joint, what would happen on rough or uneven track?

It would bend or break rods.

How are most brasses held on rods?

By straps which are bolted on the end of rods, the brasses fitting in the straps.

Are there any other forms?

Yes; a solid bushing fitted into the end of rods.

What advantage has the divided brass over a solid bushing?

The divided brass can be reduced to fit pin as it wears. The solid bushing must be renewed when worn.

How are the brasses held to pins?

By keys which are tapered or wedge shape, which take up the space between strap and bars when driven down.

How many keys are used to one set of brasses?

Generally two, one on each side of brass, although some use only one, especially on the back end of main-rod.

Are there many main-rods having the back end without straps?

Yes; strap being solid with rod, using a block and bolt to hold brass in. This is called forked or spade handle rod.

Can this rod be taken down in all positions?

No; it cannot be taken off pin on the forward centre.

What causes the pins to become hot?

It is mostly caused by not getting any oil to the pins, due to the oil-way becoming stopped up by dirt or waste, regulator or needle working down, brasses keyed up too tight or out of line, also metal thrown out filling oil-way up, and for the want of oil in cup.

What should be done when pin becomes warm?

Oil-cup should be examined for any of the above defects, and if the pin is very warm would cool it off. Raise regulator if the cup was full of oil, to let it feed more freely. If oil feeds freely and pin still runs warm, would slack up on keys, using judgment in doing so.

Is there any particular position in which to place crank-pins when keying up side-rods?

Yes; the pins should be placed on either forward or back centre.

Why is this done?

So that the pins will be in the centre-line of motion through driving-wheel, or at the extreme point of travel of pins through the centre-line of motion.

If placed on any other point, what would be the result of hard keying?

The rod could be made shorter or longer.

What would be the result if keyed in that way when pin came on the centre?

It would bend or break the rods; or if not keyed that much, would cause pins to run warm.

In what position is the main-rod usually placed?

Mostly on the top quarter, so as to bring the wrist-pin brass on the largest part of pin.

What would be the shape of a wrist-pin much worn?

Oblong; as the pin does not revolve, and the wear is front and back, due to the push and pull of piston-head.

Is there any particular pin to key in keying side-rods?

That depends on the kind of rods and the number of keys to a brass.

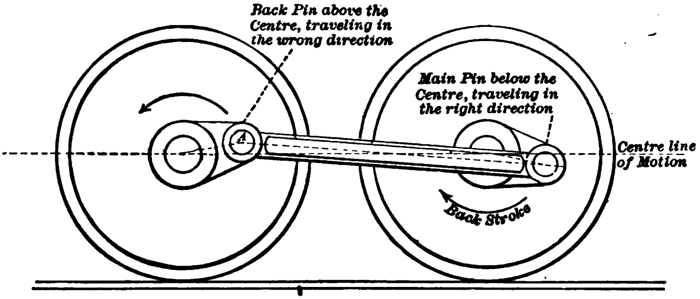
CHAPTER VI.

BREAKING OF RODS.

WHEN an engine breaks a side-rod, strap, or pin, the opposite rod must be taken down; also on an engine having four driving-wheels; and it should never be started unless this is done, as it is liable to break the good rod or pin. If the engine should slip when on the centre, it will do this, and it is liable to go either above or below the centre-line of motion, or in the opposite direction to that of the main-pin.

The reason for this is that there is nothing to guide or pull the pin in the proper direction, as when two rods are connected to their respective pins. This rule applies to all classes of engines, but it is not necessary to take all the side-rods down on all engines, as will be explained.

It has been argued that one side-rod could be run without any danger, as the main-pin would pull the back-pin around in the right direction, if it went over the centre. This is all a mistake, as will be seen by Fig. 30, which shows the engine in the forward-motion back-stroke. The back-pin has passed above the centre, due to the backward push of the piston, and having no side-rod on the other side to guide, it was free to go either way if the driving-wheels slipped. Some think that with the engine going forward, with the pins in this position, the pin would be pulled down below the centre-line of motion; but this cannot occur: as the main pin is travelling backward, it is pushing the other pin away from the centre in the direction of the arrow, and under no circumstances can that pin (*A*) come below the centre, unless it breaks or buckles the rod. Then, due to the forward motion of the engine, the wheel would reverse itself. So the reader will readily see why side-rods should come down when one is broken; as on the consolidation engines, where the rods are divided into sections, if a back or a forward section breaks it is only necessary to take down the opposite section, but if a middle section breaks, all the side-rods on both sides must come down, for the reason that when a middle section breaks, all the support for the other sections is gone, the knuckle-joint being on each end of the middle section. This must be done in case a pin holding or a middle section, a strap, or bolts breaks.


Back Pin above the Centre, traveling in the wrong direction
A
Main Pin below the Centre, traveling in the right direction
Centre line of Motion
Back Stroke

Showing the action of an Engine which is run with only one Side Rod. The back Pin has passed above the Centre.

FIG. 30.

On six-wheel connected engines the side-rod is in two sections, the forward section back end having the knuckle-pin.

If a back section breaks, the opposite section must come down. If a forward section breaks, all the side rods must be taken down. When the main-rod breaks, the engine must be disconnected, as when a valve-rod breaks. If both rods break, it is not necessary to take side-rods down for towing.

Taking down side-rods reduces the power of the engine to pull a train, in proportion to the number of drivers disconnected, as the tractive force becomes in excess of the adhesive force or power, which is due to the weight on drivers, and this causes an engine to slip when under steam if the throttle is opened wide.

Broken driving-axles often occur, and the wheel is thrown off, usually breaking side-rods and main rod or pins.

If a main driver breaks off outside of box, the engine should be brought in with the good side, taking down all side-rods. The box on broken side should be blocked up, putting a block between the top of box and top of frame, and also between the bottom of box and pedestal-cap; this prevents the axle from binding, and keeps the box in position.

QUESTIONS.

If a side-rod breaks, what must be done before starting engine?

The side-rod on the other side must be taken down.

Why must this be done?

So that the good rod may not be broken.

Why would the good rod be broken if left up?

If the engine stopped at either centre, the back crank-pin would be liable to go either above or below the centre-line of motion, there being no rod on the other side to pull it over the centre. If it went above the centre, as in Fig. 30, it would break the rod or pin.

If the pin passed above the centre, could the main pin pull it back again?

No, that would be impossible without breaking either rod or pin.

When a back or forward section breaks on a consolidation engine, must all the side-rods come down?

No, only the front or back section, on the other side.

When the middle section breaks, what must be done?

All the side-rods must come down on both sides; the same must be done if a pin, strap, or bolt breaks on a middle section.

Why must all come down?

On account of the knuckle-joints being on each end of the middle section, thus leaving no support for the front and back sections.

When a main pin breaks on a six-wheel connected engine, what must be done?

All the side-rods must be taken down on both sides, and when only a back section, the opposite section is taken down.

What effect does disconnecting side-rods have on an engine?

It reduces the power of the engine to haul a train, in proportion to the weight on each driver disconnected.

How does the engine act when the throttle is open?

The engine will slip, because the tractive force is in excess of the adhesive power.

Can an engine be run when an axle breaks outside of box?

It can be run.

When an axle breaks in the centre, what should be done?

The wheels should be blocked up to clear track, and disconnected.

CHAPTER VII.

VALVE-MOTION.

THIS is a portion of a locomotive which often remains a mystery to many. The writer will endeavor to make it as plain to the reader as possible. Starting with the valve, which (as has been shown in a previous chapter) is a hollow shell in the form of the letter D, this valve slides over the steam-ports, controlling the inlet and outlet of steam; also the exhaust.

Lap is the amount that the valve extends over the edge of the steam-ports, when the valve is in the centre of its travel, as in Fig. 31. The purpose of lap on a valve is to get an increased amount of expansion from the volume of steam used in the cylinders. Increase of lap is increase of expansion, to a certain extent, as the valve will release the steam earlier in the stroke if the exhaust side of valve is line on line with steam-ports,

Inside lap is the amount that the exhaust side of valve overlaps the port, as in Fig. 32, which causes the valve to exhaust the steam later in the stroke; but then it will close the valve earlier to the exhaust, and cause greater compression.

Inside clearance is the amount that the port is open on the exhaust side of valve, when in the centre of its travel, as in Fig. 31. In this the valve will exhaust the steam earlier in the stroke of the piston, but will close the exhaust later, thus reducing the compression. With a valve without lap, the steam would follow full stroke without expansion, which would be wasteful.

Lead of a steam-valve is the amount the valve has opened port when the crank-pin is on either centre. The idea of having lead is to provide a cushion and help start the engine off centre. There is a great difference in opinion as to how much lead an engine should have, but generally freight engines are given one eighth lead, full stroke, and passenger engines one sixteenth.

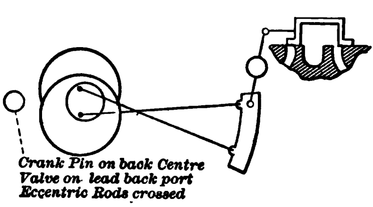
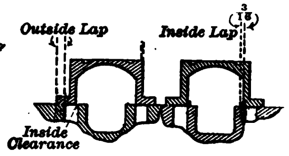


FIG. 36.



Lap and Clearance of Valve

FIG 31. FIG. 32.

Valve-motion is composed of several parts, as Fig. 33 shows. We will start with the eccentrics which are fastened onto the main drivers. As a rule, the eccentric encircles the main shaft, and is the only substitute for a crank. There are four on an engine using the Stephenson or link motion, two for a link—the forward-motion eccentric, which controls the motion of the valve when running forward; the backward eccentric, which controls the motion of the valve when running backward.

Eccentric sheaves or wheels are made in two parts, and bolted together by studs, as in Fig. 33. The method of fastening to the axle is by a key and set-screws. The travel of the valve is controlled by the travel of the centre of eccentric in a horizontal line each side of the centre of axle. Thus if we had a valve whose travel was four inches we would place the centre of the eccentric two inches above the centre of axle or horizontal line *AB* in Fig. 34; then when the axle revolved, the centre of eccentric would travel just four inches in a horizontal line, which would be the travel of valve.

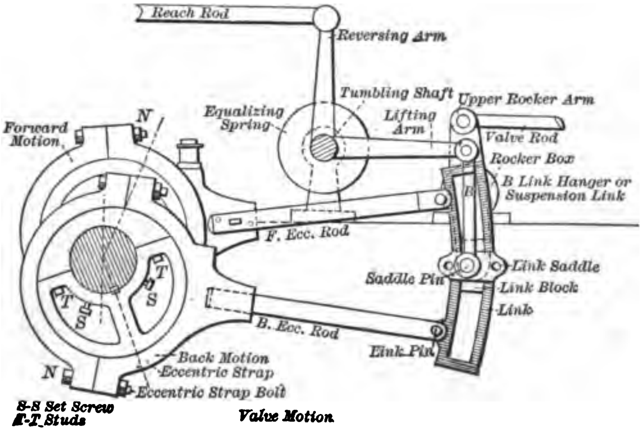


FIG. 33.

There is, however, another point with which we must deal, and that is the lap and lead of valve: this, then, will cause the centre of eccentric to be moved beyond the vertical line *CD*, in Fig. 34, just the amount of lap and lead of valve, which in this case may be thirteen sixteenths of an inch,—three-fourths lap *plus* one-sixteenth lead,—which is called the angular advance of the eccentric center. If this were not done the piston-head would leave the end of the cylinder before the valve would open, as the valve would have to travel the length of lap and before it would open the port of the cylinder; in that case the piston-head would lead the valve.

It is often asked if reducing the diameter of the eccentric would diminish the travel of valve. The answer is: No, not so long as you do not change the position of eccentric centre to that of the axle, but it would require an eccentric-strap of smaller dimension. Eccentric-straps are made in two pieces, as in Fig. 33, and are bolted together by strap-bolts *N* and *N*. In order to keep the strap on the eccentric, the straps are made hollow, with a flange in each side, which fits the eccentric.

Fastened to the eccentric-strap is the eccentric-rod, which connects the strap with the link. This rod is fastened into the strap by three bolts. The middle hole is usually made oblong, so as to allow the rod to be shifted when setting the valves.

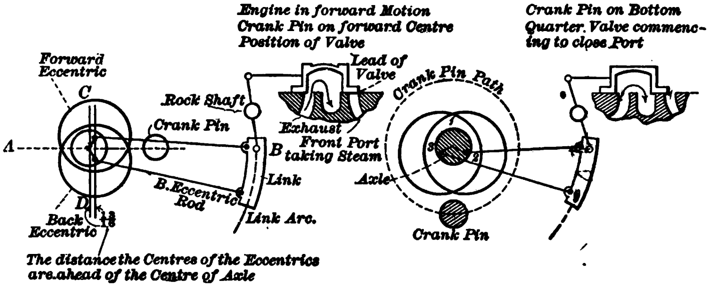
The forward end of the eccentric-rod is forked, spanning the link, as in Fig. 33. This end of the rod is fastened to link by the link-pin, which runs through the eye in link and fork of rod. This construction is the same for the forward and backward motions.

As usually constructed, the forward eccentric is next the driving-box, and the backward inside. In all indirect motion using a rock-shaft, the forward eccentric-rod is connected to the top of the link. The link is simple in its construction, but is an important feature in valve-motion, as by its use the motion is reversible, or the engine can be run either forward or backward.

As generally made, it is forged solid; but some builders make the two sides separately, and use a block top and bottom, putting a bolt through them, binding it together as a link.

The link is not straight, but is curved, having a given radius. This radius is measured from the centre of the axle to the centre of link, as in Fig. 33.

The reason for making a link with a radius is on account of the link being raised and lowered each side of the centre-line of motion, and if straight it would throw the valve out in its travel.



(Showing the Action of Valve Motion)

FIG. 34. FIG. 35.

On the back of the link is a cross-piece called the saddle, and spanning the link on this saddle is a pin, which is called the saddle-pin. This is the axis on which the link rotates or swings.

From this saddle-pin to the lifting-arm is the link-lifter or suspension link, which is attached to lifting-arm, which in turn is welded to tumbling-shaft, the tumbling-shaft having two arms, lifting and reversing. Attached to the reverse-arm is the reach-rod. This is connected to the reverse-lever, as in the cab. Within the link-slot is a block called the link-block. This link-block has flanges on it to keep it in the link. Fitting in this block is the lower rocker-arm pin. The rocker-shaft has two arms, the upper and lower. To the upper arm is attached the valve-rod, and the lower arm as just stated is connected to link-block.

Remember that in the forward motion the valve is controlled by the forward-motion eccentric, and the centre of link is below the centre-line of motion, and we will try to explain the operation of motion and the reason why raising and lowering the link reverses the motion. By looking at Fig. 34 we see that the crank-pin is on the forward centre, and the eccentrics are ahead of the centre of the axle an equal distance, which is the lap and lead of valve. The link is all the way down, or in full forward motion. This being an indirect motion, it must be remembered that the upper rocker-arm travels directly opposite to that of the lower arm, or centre of the eccentric. A good rule for remembering the difference between a direct and indirect motion is, that in an indirect motion the centre of the eccentric follows the crank-pin, and in a direct the crank-pin follows the eccentric centre.

By referring to Fig. 35 you will see that if the crank-pin was to travel from the forward centre downward to the bottom quarter, or near that point, the centre of eccentric would travel from 1 to 2, and the valve would travel back and uncover port full, the valve having travelled back while the eccentric centre went ahead.

If the crank-pin continues to travel to the back centre, the valve would start forward and close the port, and when the crank-pin is *on* the back centre the valve will be on the lead, on the back-port, as in Fig. 36. The steam begins to exhaust from the front port as soon as the valve passes the centre of travel when line on line, and no inside lap; and so on, the full revolution of the driver.

The valve uncovers and covers the port, and comes on the lead when the crank-pin passes from one centre to another, at the same time exhausting the steam out of cylinder.

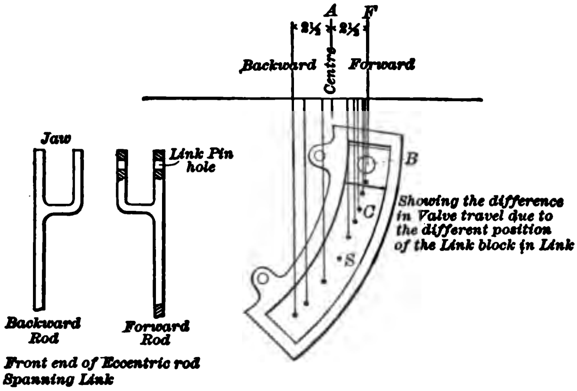

A
F
2½
2½
Backward
Centre
Forward
Jaw
Link Pin hole
B
C
S
Showing the difference in Valve travel due to the different position of the Link block in Link
Backward Rod
Forward Rod
Front end of Eccentric rod Spanning Link

FIG. 37.

We will now explain why raising and lowering the link short-strokes the valve, and also reverses the motion of the valve, in as simple a way as possible. By referring to Fig. 37, which is an outline of link, let us consider the link as a lever, with its fulcrum at *S* or the saddle-pin. Then if the link should be moved forward from the vertical line *A* to what would be full forward travel of link, the dot *B* would move from *A* to *F*; but with the same movement of link the dot *C*, midway between the dot *B* and fulcrum *S*, would move only half as far as *B*. Thus it is with the link-motion if the link is all the way down in the forward motion. The link-block will be in top of link-slot, and is controlled wholly by the forward-motion eccentric; now if the link is raised the block will be further down in link, or at dot *C* in Fig. 37, and would travel only half as far as when top of link-slot.

When in this or any other point between full stroke or top of link-slot and centre of link, the valve is being short-stroked, and is partly controlled in its movements, by both eccentrics.

The action is the same for backward motion. When the link-block is in the bottom of link-slot the engine is in the backward-motion full stroke and the valve is controlled by the backward motion eccentric; and when the link is raised up toward the centre, the valve is being short-stroked, the same as in the forward motion.

Raising or lowering the links also will reverse the motion of valves and engine. The position of the centre of the eccentrics, in connection with the link, controls this action.

By Fig. 35 it will be seen that the link is in full forward travel and the port is full open. The centre of the eccentrics is at 2 and 3, while the crank pin is not quite at the bottom quarter.

The reason for this is that the centres of the eccentrics are not at right angles with the crank-pin, but are moved forward the length of the lap and lead.

Drawing the vertical line *ON* in Fig. 38, the link-block centre is at 7, or forward of the vertical line *ON*, while the bottom of link is back of the vertical line *ON*.

To reverse the motion, the links are raised, and the link-block will be in the lower part of link-slot. It must not be forgotten, that in the act of raising the link it changes its position very slightly, but slides up over the link-block, the slot acting as a guide to the link-block, which in turn moves the rocker-shaft and valve. When the link is raised from the full forward motion to the backward motion, the block will then be in the bottom of link-slot, having moved from the line *T* in forward motion to the line *P* back of the vertical line *ON* in Fig. 39, and has moved the valve across the seat and uncovered the back-port, reversing the motion of the engine.

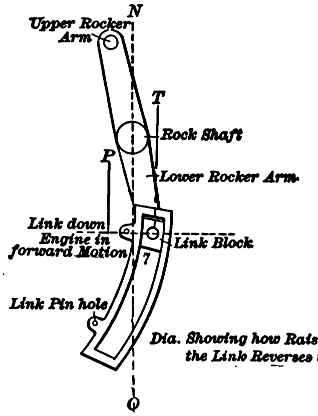
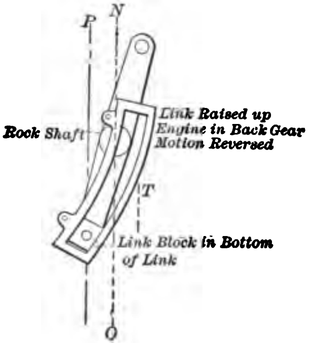


FIG. 38.


P
N
Link Raised up Engine in Back Gear Motion Reversed
Rock Shaft
T
Link Block in Bottom of Link
O

Dia. Showing how Raising or Lowering the Link Reverses the Motion

FIG. 39.

Remember, too, that the link-block must follow the slot in link, and the rocker-arm must move whichever way that the link is inclined, either side of the vertical line *NO*.

The question is often asked: "Does the lead of opening increase as the links are raised up?" I answer that it *does* increase, for the reason that it is due to the position of the centre of the eccentric. If the straps of the eccentric-rods encircled the axle, their centres in line with the centre of the axle, this would not occur; but as they move around the centre of the eccentrics, whose centres are out of line with the centre of the axle, also as the radius of the link is taken from the centre of the axle, then, if the crank-pin is on the forward centre and the link raised, the centre of the eccentric will shove the links ahead, which increases the lead-opening of the valve. As this action takes place on either centre, or as the links are raised up while running, the shorter the travel of valve, the greater the lead.

QUESTIONS.

What is meant by the lap of valve?

The amount that the valve extends over the edge of steam-port when the valve is in the centre of travel.

Why does a valve have lap?

In order to get an increased amount of expansion in the steam-cylinder.

How does a valve without lap act?

Cylinders would take steam throughout the whole stroke, which is not economical when not using a cut-off.

What is meant by the lead of a valve?

Lead is the amount that the port is open when the engine is on either centre.

Why is lead given to a valve?

To form a cushion for the piston-head; and at the same time, if the compression is in excess of the pressure in the chest, it will allow it to equalize.

Why is a cushion required in a cylinder?

To prevent the piston-head from striking the cylinder-head, also to retard the motion of the reciprocating parts.

What is meant by the inside lap of valve?

It is the amount that the valve extends over the edge port on the exhaust side of valve, as in Fig. 32, which shows three-sixteenths lap on inside.

Why is a valve given inside lap?

In order to increase the expansion, by preventing the steam from exhausting as soon as it would if there were no inside lap; but it produces an earlier cut-off of the exhaust.

What is the inside clearance of a valve?

It is the amount that the port is open on the exhaust side when the valve is in the centre of its travel.

Why is it used in a valve?

To produce a later closing of the valve to the exhaust, by reducing the back pressure or compression, but at the same time it reduces the amount of expansion by an earlier exhaust-opening. (See Fig. 31.)

What is the most common form of valve-gear which is used on the American locomotive?

The link-motion. The names of the parts are shown in Fig. 33.

What governs the travel of the valve?

The throw of the eccentric or the distance the centre of eccentric travels in a horizontal line, providing that the rocker-arms are of equal length.

What is the position of the eccentric centres when the engine is on the forward centre?

The centres are in front of the centre of axles, or line *CD*, as in Fig. 34.

What distance are they ahead of the line *CD*?

The length of the lap and lead of valve.

Why must they be in advance of the line *CD*?

If they should be at right angles with the crank-pin, the piston would leave the end of cylinder before the valve opened the steam-port. This is called the angular advance of the centre of the eccentric, and is equal to the lap and lead of valve.

In how many parts are the eccentrics?

They are made in two parts, so that they can be put on an axle.

How are they joined together, and fastened on an axle?

The parts are fastened together by studs, as in Fig. 33, and then fastened to the axle by set-screws *SS* in Fig. 33. A key is also provided.

On what axle are the eccentrics usually attached?

Mostly on the main driving-axle.

What is an eccentric-strap?

An eccentric-strap encircles the eccentric, and has the back end of eccentric-rod attached to it.

How are the parts of the strap fastened together?

By strap-bolts, as in Fig. 33.

In a locomotive valve-motion, how many eccentrics are there?

Four—a forward and a back-up eccentric for each valve.

To what part of the link is the forward-motion eccentric-rod generally attached?

To the top part of the link; the end of the rod is forked, spanning the link.

What is the use of the link in the valve-motion?

By using the link the motion of the engine can be reversed, and the valve can be short-stroked.

What is the radius of the link, and why is the link curved?

The radius is the distance from the centre of the axle to the centre of the link or link arc. The link is curved on account of being raised and lowered, rotating around a centre with the curve in the link. The moving of the link up or down does not make the travel unequal, as it would if it was not curved.

What is the link-block?

The link-block fits in the slot of link, and is attached to the lower rocker-arm pin.

What are the saddle and saddle-pin?

The saddle is a plate spanning the link, to which the saddle-pin is fastened, the saddle-pin forming an axis for the link. To the saddle-pin is attached the link-hanger or suspension-link.

What is the use of the tumbling-shaft?

A tumbling-shaft* runs across the frame, carrying the lifting-arms, and also the reverse-arm, to which the reach-rod is attached. To the lifting-arms is attached to the link-hangers.

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* Also called lifting-shaft.

What is provided to counteract the weight of the links, eccentric-rods, and tumbling-shaft?

An equalizing-spring, which takes the weight and makes the links easy to raise and lower.

Are the rocker-arms used in all valve-motions using a link?

Only in indirect motion.

Are they always of the same length?

They are of different lengths when the travel of the valve is greater than the throw of the eccentric.

Should the steam-ports be covered when the engine is on either centre, with a valve having lead?

No; the valve will be wider open when in the out notch than when full throw, even when on the centre.

Why does this increase of lead occur?

On account of the position of the centres of the eccentrics and the movement of the link.

Why does the raising or dropping the link reverse the motion?

The motion is reversed by the position of the link, or in whatever position the links are. This position is governed by the centres of the eccentrics, and as the link is raised or lowered the link-block must follow the slot of the link, which acts as a guide to the block. (See Figs. 38 and 39.)

BREAKING DOWN OF THE VALVE-MOTION.

When an eccentric-rod breaks, what must be done in the way of disconnecting?

Both eccentric rods and straps must be taken down.

Cover port and disconnect as for a broken valve-rod. (See Fig. 15.)

If the forward-motion eccentric was broken, could the engine be run without taking down both rods?

Yes, by disconnecting the link-hanger, and letting the link carry on top of the link-block.

If the eccentric became loose on the axle and shifted, what could be done to fasten it in place, the key and sets-crews of that eccentric being lost?

Take the two set-screws from the other eccentrics and fasten it. There are eight set-screws on the shaft.

Is it possible to break a backward-motion strap, and not take down the eccentric-rods?

This can be done by fastening the back end of rod fast to the forward motion.

Could the engine be reversed on that side when the back-up rod is fast to forward-motion rod?

No, it should be in the forward motion on that side, because there is only one eccentric that controls the motion, that being the forward eccentric.

Would an engine hold if reversed in that condition?

No, as it would not have any braking-power.

When an eccentric slips or is moved away from the proper position, there being no key-way for a guide, how would it be possible to set the eccentric so as to bring the engine in on the road?

The proper way to do this is to place the engine on the forward centre, and set the slipped eccentric by the good one. If it is the back-up eccentric that has slipped, put the reverse-lever in full forward notch, and make a mark on the valve-stem, close to the stuffing-box. After this is done, put the reverse-lever in full back notch, and move the loose or slipped eccentric around until the mark on valve-stem comes back to stuffing-box; then fasten eccentric, and it will be in proper position. This applies as well to the forward eccentric. If slipped, set it by the good one or back-up eccentric.

Why is it possible to set one by the other?

Because when on either the forward or back centre the eccentric centres are the same distance ahead of the centre of axle, as in Fig. 34.

Are there any other ways of setting a slipped eccentric?

There are other ways, but the one referred to is the best. It can be done by using the cylinder-cocks as a guide. If engine is on the forward centre, move the eccentric until there is but little steam escaping from the front cylinder-cock. This will place the eccentric nearly right.

When a link-hanger, tumbling-shaft, lifting-arm, or reach-rod breaks, what should be done?

When link-hanger, saddle-pin, reach-rod, or tumbling-shaft breaks, it would leave the links dropped down on top of the link-block, and the best thing to do is to fit blocks in the links, as in Fig. 40. When a link-hanger or saddle-pin breaks, blocks should be put in that link only; if running in the forward motion, the reverse-lever should be put in the position that the engine will be run, and then measure the distance from the top of link to the link-block, on the good side; that will the length of block to be put on top of link-block on the broken side. This will be a short block. When running in the backward motion, the link-block will be in the bottom of the link, as in Fig. 41, and then it will require a long block on top of the link-block. A hole should be bored through it to fasten it to link. This rule is applicable to several breakdowns.

If running a fast passenger train, would it be policy to stop and block other lines by doing as directed in the former rule for the breaking of saddle-pin or link-hanger?

No; would leave link carry on link-block, putting some waste between block and top of link, and proceed.

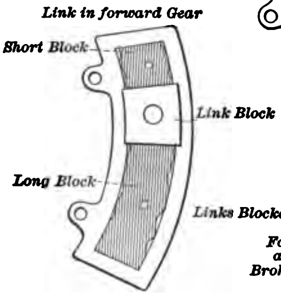

FIG. 40.

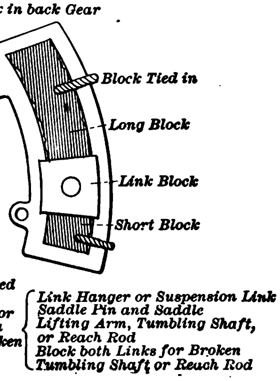
Link in back Gear
Block Tied in
Long Block
Link Block
Short Block
Links Blocked
For a Broken
Link Hanger or Suspension Link
Saddle Pin and Saddle
Lifting Arm, Tumbling Shaft, or Reach Rod
Block both Links for Broken Tumbling Shaft or Reach Rod

FIG. 41.

When a link-block pin or lower rocker-pin breaks off, what should be done?

Would get the block, if possible; disconnect the valve-rod from the upper rocker-arm cover ports and disconnect main-rod, push the lower rocker ahead to clear the link, and fasten; then proceed with train. This applies the same when a lower rocker-arm is broken.

How can a valve be put in the centre of seat, to cover ports?

By the reverse-lever. If the crank-pin is off the centre, by putting the reverse-lever in centre notch, or by opening the cylinder-cock and moving valve until the steam disappears, then move valve one half an inch or more, and the valve will have ports covered.

Why not shove them all ahead or back, and leave one port open?

The valve would drop from the seat to the receiving-port, which would cause the valve to be cocked up on seat, and the steam would blow out the exhaust-port, and one port should not be open to cylinder.

CHAPTER VIII.

VALVE-SETTING.

LOCOMOTIVE-ENGINEERS, as a rule, do not set valves, but it is nevertheless a subject that should be understood.

Valve-setting is usually done in the shop, by a person who has had experience in that class of work.

The first thing to be done when setting valves is to get the crank-pin in the dead-centre, and the best way to do this is shown in Fig. 42. First put the crank-pin below the centre (as in dotted line) so that the cross-head will be near the end of its travel in the guides. Make a mark on the guide at the end of the cross-head shoe, as in *A*. At the same time take a tram and scratch an arc of a circle on the centre of the tire *EE* in figure; then put a punch-mark in wheel-cover or any convenient point, put a tram point in that punch-mark in cover with the other end of tram, and scratch a line across the arc on wheel, as in *B*. Now with the line on guide-bar and the line at *B* move the driving.wheel around in the direction of the arrow in figure until the cross-head shoe comes back to the mark on guide-bar; then with the tram scratch another line across the arc on tire, as at *C*, the point of tram being in the punch-mark of wheel-cover, as in the first case. Next, find a point on arc *EE* half-way between the punch-marks *B* and *C*, which is *S*. Now move the driving-wheel back until the point of tram comes in the punch-mark *S*, and the mark on wheel-cover. The crank-pin will then be on the centre, and the end of cross-head be at the line *N*. This method will do for either centre; only the marks on wheel will be on different parts of the tire.

After the crank-pin is on the centre the valve-setting begins. The eccentrics are generally fastened on in their proper positions by a key. The links being all the way down, the next point is to find the proper length of the eccentric-rods.

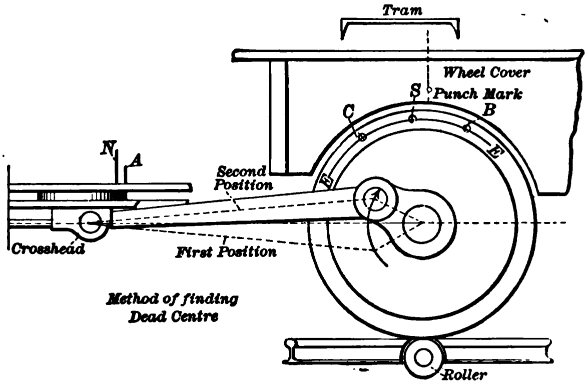

FIG. 42.

The valve in steam-chest is given the proper amount of lead, and a piece of wood or tin the thickness of lead is put between valve and port holding the valve, the valve-rod being connected to valve and rocker-arm.

The eccentric-rod is then fastened to link; and as most rods have oblong holes in them to allow them to be moved, the rod is connected to the strap and the nut tightened up and the wheel moved around to the back centre; and if the lead-opening is the same as for the front port, the rod is of the proper length, and then the two other holes are marked on the eccentric-strap and bored out. But in an engine which has been running the eccentrics must be lengthened or shortened by contracting or expanding in a forge, which is done by a competent smith.

Next find the length of the backward eccentric-rod as in the forward, except that the lever is in full back gear. Try it on both centres, as before.

When an engine has become lame after being run for some time, the valves are found to be opening the ports unequally, that is, one port is open wider than the other, with the same travel on the valve. There is no difference in the travel of the valve over the seat, but the centre of the travel of the valve has been moved either ahead or back of the centre of the valve-seat.

This will cause the valve to cut off unequally, and one end of the cylinder is doing more work than the other. This can be told by the exhaust, and to rectify this the eccentric-rod should be lengthened or shortened, as the case may be; for if the valve opened wider on the front port, then on the *back* one the eccentric-rod must be shortened, which will change the centre of valve-travel, or throw the valve ahead and equalize the port-opening. The amount must be determined by the one setting the valves.

When the back port is open more than the front port; then the eccentric-rod must be lengthened, and the valve will be drawn back to the centre-line of the valve-seat.

When an eccentric is shifted, it can be easily known by the lead-opening. As an example, the writer was on an engine which broke a valve-stem and eccentric-straps, and for some cause the eccentric became shifted, and when the valve-setter put the gear up again, the engine had fully one-quarter lead with the valve that was used before, the lead being almost equal for both ports. The valve-setter was puzzled, when the writer suggested that he examine the eccentric centre, which he did, and found the trouble at once, moved the eccentric back in its place, and the lead was all right.

Valves cannot be made to cut off equally, on account of angularity of rod-motion; but when an engine is running along, and there are two heavy beats and two mild beats or exhaust, the trouble is that one engine is working stronger than the other, and it is caused by the link-blocks being in different positions of the link. A link-hanger that is longer on one side will cause it, and should be shortened, or both made the same length.

Another cause is, that one saddle-pin is worn more than another, or eye in link-hanger, or the tumbling-shaft boxes being of different heights. The cause very often of valve being out is the wear of driving-boxes between shoe and box; the wedge is back of box, and wear is taken up at that point, throwing the axle ahead that moves the eccentric also. In order to find the position of reverse-lever for different cut-offs, move the piston-head from the end of cylinder the number of inches that is wanted for cut-off, and then raise links up until the valve closes the port, and mark point on quadrant.

TABLE I.

Travel of Valve.	Middle of Port-opening.		Point of Cut-off.		Point of Release.		Lead.
	Backward Stroke.	Forward Stroke.	Backward Stroke.	Forward Stroke.	Backward Stroke.	Forward Stroke.	
2½	11/32	5/16	8	6¾	17	16⅝	9/32
2⅝	7/16	11/32	9½	9½	18⅝	18 5/16	¼
2⅞	9/16	½	12	11¾	19¾	19 9/16	7/32
3⅛	11/16	41/64	14	14	20 11/16	20 9/16	3/16
3½	⅞	27/32	16½	16½	21 11/16	21½	5/32
4	1⅛	1 3/32	18¼	18⅛	22⅝	22¼	⅛
4½	1¼	1¼	19⅝	19½	23 13/16	22¾	3/32
5	1¼	1¼	20⅝	20½	23⅛	23⅛	1/16

Travel of valve	5
Steam-ports	1¼
Exhaust-ports	2¾
Lap of valve	⅞
Inside lap of valve	1/16
Lead full stroke	1/16

Table II shows the different travel and point of cut-off of two valves, one having 5-inch throw or travel and ⅞ lap, the other 3½ throw and ½ lap, both cutting off at the same point, showing the difference in port-opening between a long- and short-throw eccentric.*

TABLE II.

Point of Cut-off.	Width of Opening of Steam-ports. Eccentric 5-inch Throw.	Eccentric 3½-inch Throw.
6 inches	7/32 inch	5/32 inch
8 "	9/32 "	3/16 "
10 "	11/32 "	7/32 "
12 "	7/16 "	9/32 "
15 "	5/8 "	3/8 "
18 "	31/32 "	1 1/16 "
21 "	1 1/4 "	1 1/32 "

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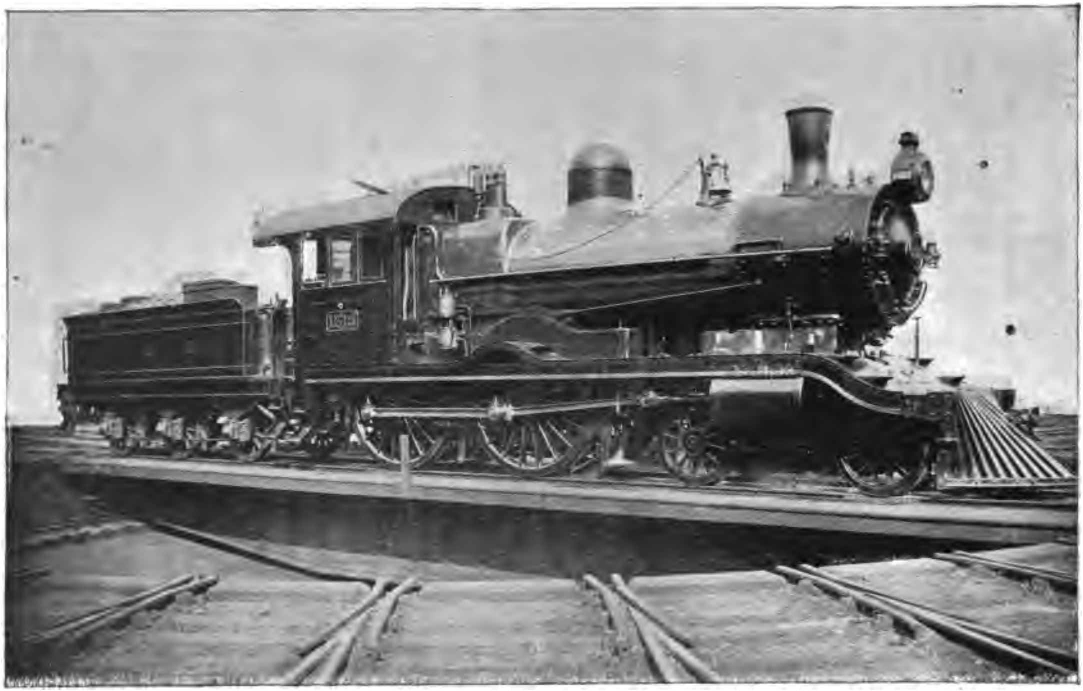
*M. N. Forney.



PENNA. R. R. TWO-CYLINDER COMPOUND, LINDEUER SYSTEM.

Cylinders, $\overset{\text{H. P.}}{19\frac{1}{2}''} \times \overset{\text{L. P.}}{31''} \times 28''$ stroke. Diameter of Drivers, 7 feet.
Diameter of Boiler, 60". Steam-pressure, 205 pounds.
Weight on Drivers, 90,000 pounds (about)

CHAPTER IX.

THE COMPOUND LOCOMOTIVE.

LOCOMOTIVE-BUILDERS, in endeavoring to keep the locomotive ahead as a motive power, have been advocating the compound engine, of which many have been built in this country and are being handled by our engineers and firemen. The idea of a compound engine is the saving of fuel, which means dollars and cents to any railroad company.

The different methods of compounding are the two-cylinder and the four-cylinder, also the three-cylinder, in which two high-pressure and one low-pressure are used.

ELABORATE TEST OF COMPOUND ENGINES.

It is not claimed for compound locomotives that a heavier train can be hauled at a given speed than with a single-expansion engine of similar weight and class. No engine can haul more than its adhesion will allow; but a compound will, at a very low speed on heavy grades, keep a train moving where a single-expansion engine will slip and stall. This is due to the pressure on the crank-pin on the compound being more uniform throughout the stroke than is the case with a single-expansion engine.

The principal object in compounding locomotives is to effect fuel economy, and this economy is obtained—

1. By the consumption of a smaller quantity of steam

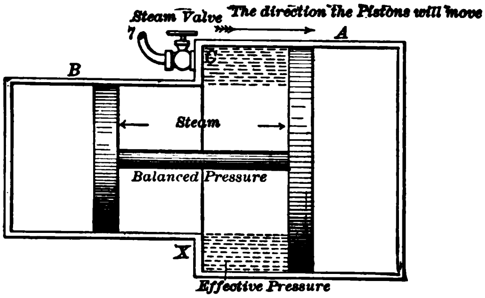
in the cylinders than is necessary for a single-expansion engine doing the same work. 2. The amount of water evaporated in doing the same work being less in the compound, a slower rate of combustion combined with a mild exhaust produces a higher efficiency from the coal burned. In a stationary engine, which does not produce its own steam-supply, it is of course proper to measure its efficiency solely by its economical consumption of steam. In an engine of this description the boilers are fired independently, and the draught is formed from causes entirely separate and beyond the control of the escape of steam from the cylinders; hence any economy shown by the boilers must of necessity be separate and distinct from that which may be effected by the engine itself. In a locomotive, however, the amount of work depends entirely upon the weight on the driving-wheels, the cylinder dimensions being proportioned to this weight; and whether the engine is compound or single-expansion, no larger boiler can be provided, after allowing for the wheels, frames, and other mechanism, than this weight permits.

Therefore the heating-surfaces and grate-area are practically the same in both types, and the evaporative efficiency of both locomotives is determined by the action of the exhaust, which must be of sufficient intensity in both cases to generate the amount of steam necessary for utilizing, to the best advantage, the weight on the driving-wheels.

This is a feature that does not appear in a stationary engine, so that a compound locomotive cannot be judged by stationary standard, and the only true comparison to be made is between locomotives of similar construction and weight, equipped in one case with compound and in the other with single-expansion cylinders. One of the legitimate advantages of the compound system is, that, owing to the better utilization of the steam, less demand is made upon the boiler, which enables sufficient steam-pressure to be maintained with the mild exhaust, due to the low tension of the steam when exhausted from the cylinders. This milder exhaust does not tear the fire, nor carry fuel unconsumed through the flues into the smoke-box and from there out of the smoke-stack, but is sufficient to maintain the necessary rate of combustion in the fire-box, with a decreased velocity of the products of combustion through the flues.

The heating-surfaces of a boiler absorb heat-units from the fire and deliver them to the water at a certain rate. If the rate at which the products of combustion are carried away exceeds the capacity of the heating-surfaces to absorb and deliver the heat to the water in the boiler, there is a continual waste, that can be overcome only by reducing the velocity of the products of combustion passing through the tubes. This is effected by the compound principle. It gives, therefore, not only the economy effected by a smaller consumption of water for the same work, but the additional economy due to slower combustion, It is obvious that these two sources of economy are interdependent. The improved action of the boiler can be obtained only by the use of the compound principle, while the use of the compound principle enables the engine to develop its full efficiency under conditions which in a single-expansion engine would require a boiler of such large capacity as to be out of the question under circumstances usually governing locomotive construction. Also, the compound system prolongs the life of the boiler by decreasing the demand on it for steam.

We will now endeavor to explain the system of compounding, so that it may be understood by the beginner. To many who are handling our present locomotive it seems a difficult question to solve how any effect can be produced by the additional expansion. The back-pressure seems to be the most troublesome point.



Showing the action of two Piston Heads on one rod with Steam between them

FIG. 43.

Those handling engines frequently ask the question: "How can the steam exert any more power after once expanding the high-pressure cylinder? Will not the pressure against the high-pressure piston counteract any power thus derived?"

By referring to Fig. 43 will be seen a simple way of explaining the effect of steam between two pistons on a single piston-rod, as in a tandem compound engine. This applies as well to any other system of condensing or non-condensing compound engine.

Fig. 43, on page 90, shows two piston-heads, *A*, *B*. Piston-head *A* is perhaps three times as large as piston-head *B*. These heads are fastened on one piston-rod. The cylinder is made to suit the diameters of the heads, there being no cylinder-head between these two piston-heads. Having connected the piston-heads and cylinder to suit, the pipe 7 is tapped into the cylinder at *C*. Now when steam is let into the cylinder between the piston-heads *A* and *B*, which way will the pistons move, or will they move at all?

The answer is, that they will move in the direction of the arrow, or with the larger piston-head *A*. This is because of the difference in area of the two piston-heads, they being exposed to the same steam-pressure per square inch. The greater pressure of power is against the larger piston *A*, thus overcoming the pressure against the smaller piston-head *B*. The effective pressure against the piston-head *A* is that represented by the dotted lines, which was resisted in its expansion by the shoulder or head on the cylinder at *X*. Thus it is shown that it is possible to connect two piston-heads on a single rod and get a movement of the piston-heads when the steam is introduced between them, the one piston-head being larger than the other. So it is with the compound engine. The low-pressure cylinders are of a larger diameter than the high-pressure cylinder. Now this figure represents the compound engine exactly. Fig. 44 is a tandem compound or four-cylinder engine. Some builders prefer this principle on account of the power being equal on both sides of the locomotive, and the powers of the high and low pressure in line with the centre-line of motion. One fact should be particularly understood, that the compound engine is supposed to use the steam that is being exhausted into the atmosphere, directly from the cylinder of a high-pressure simple engine, to a better advantage by expanding it into another cylinder before it escapes into the atmosphere.

To explain this, it will be supposed that a simple engine is being run with a train, and the initial pressure is one hundred pounds to the square inch in the cylinder. The point of cut-off is one-half stroke: then expansion take place at or near the end of stroke. It is found that the steam has been reduced in its pressure just one half of the initial pressure of one hundred pounds, which makes the terminal pressure fifty pounds per square inch when it escapes into the atmosphere. This terminal pressure varies with the point of cut-off and the initial pressure.

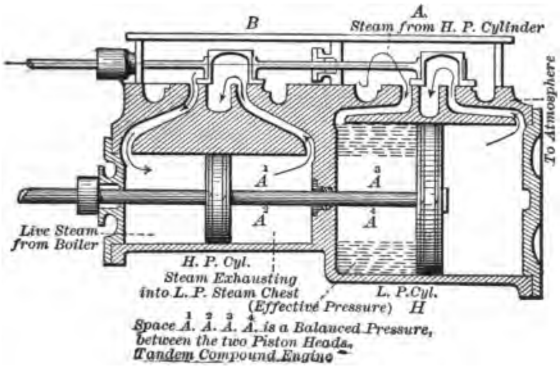

A.
B
Steam from H. P. Cylinder
To Atmosphere
$\overset{1}{A}$
$\overset{2}{A}$
$\overset{3}{A}$
$\overset{4}{A}$
Live Steam from Boiler
H. P. Cyl.
Steam Exhausting into L. P. Steam Chest
L. P. Cyl.
(Effective Pressure)
H
Space $\overset{1}{A}$. $\overset{2}{A}$. $\overset{3}{A}$. $\overset{4}{A}$. is a Balanced Pressure, between the two Piston Heads.
Tandem Compound Engine

FIG. 44.

Then it is this high terminal pressure that the compound engine saves by exhausting it into the low-pressure cylinder, causing it to expand further and to a lower terminal, as in the tandem cylinder.

In Fig. 44 the compounding is clearly shown as follows: *B* is the high-pressure and *A* is the low-pressure cylinder, corresponding to *B* and *A* in Fig. 43; but the two cylinders in this case are separated, or have a head between them, thus making them into two cylinders of different diameters. The two piston-heads are on the same piston-rod, which is connected to the cross-head. A stuffing-box is provided between the two cylinders for the piston-rod. The exhaust-steam from high-pressure cylinder passes to low-pressure chest by the pipe *O*. There are two steam-valves for controlling the inlet and outlet of steam in the cylinders, also the exhaust. As shown, the piston-heads are moving in the direction of the arrow, and the H. P. valves are cutting off steam at half stroke. This is done to illustrate the action of the terminal or exhaust pressure; steam is entering the back end of the high-pressure cylinder from the boiler, the initial pressure is one hundred pounds. The steam that was expanded in the forward end of the high-pressure cylinder whose initial pressure was one hundred pounds, cut-off at one-half stroke, expanded in that end down to fifty pounds, is now being exhausted over into the low-pressure cylinder, as shown by the arrow, and exerting its power against the low-pressure piston-head, thus getting an additional power from the steam that would have been exhausted into the atmosphere, at fifty pounds per square inch.

Then if the volume of the low-pressure cylinder was three times that of the high-pressure, and the steam was to follow the low-pressure full stroke, the average pressure throughout the whole stroke of the low-pressure cylinder would be one third of fifty pounds, or sixteen pounds.* Thus in this case, instead of a terminal of fifty pounds per square inch, as in the simple engine cutting off at the same point in the high-pressure cylinder of the compound engine, we get a terminal of sixteen. Then by getting this increased expansion in the compound engine it enables the high-pressure cylinder of the compound engine to be reduced in its area below that of the present high-pressure engine, thus reducing the amount of steam used, which represents fuel saved. The total power of the two cylinders in a tandem engine should equal the power of one high-pressure cylinder.

In calculating the power of the compound engine, the average mean effective pressure through the stroke of high-pressure cylinder per square inch is multiplied by the area of that cylinder in square inches; then find the average mean effective pressure in the low-pressure cylinder, multiply that by the area of the low-pressure cylinder, and at the same time deduct from the total power of the low-pressure piston the area of the high-pressure piston-head, multiplied by the average pressure in the low-pressure cylinder. The power remaining after this deduction is the actual power of low-pressure cylinder; this, then, added to the power of the high-pressure piston head, is the total pull or power of the steam pushing the two piston-heads.

Another deduction has to be made from this total power, and that is the back-pressure in face of the low-pressure piston-head. This is the total power of the compound engine. Fig. 46 shows the distribution of steam in the cylinders.

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* Omitting fractions.

Cylinder condensation is a point that is not usually understood,—I mean in the manner in which the term is used in connection with the compound engine. Any change in the temperature of steam causes a change in the pressure of that steam, so that the higher the temperature the more expansive the steam. In compounding, excessive cylinder condensation is thought to be reduced.

Cylinder condensation is caused in the following manner: When a cylinder takes steam, the wall of the cylinder absorbs a certain amount of heat from the entering steam, thus reducing the temperature of that steam and causing a loss in pressure. This action takes place until about the time of exhaust-opening, when re-evaporation takes place, which in a simple engine is exhausted into the atmosphere. The cause of this re-evaporation is, that when the steam has expanded to the point of exhaust it is at the lowest temperature it will reach while in the cylinder at this point, the cylinder walls being hotter than the steam. The steam that was condensed while the walls of cylinder were absorbing the heat from the incoming steam being in the form of water, reabsorbs the heat from the cylinder walls and turns into steam.

Water is a great absorber of heat, and in the compound engine this regenerated steam exerts its pressure against the low-pressure piston-head. In a high-pressure or simple engine, when expansion is long in the cylinder, it causes a great variation in the temperature of the steam.

If the steam entered the cylinder at one hundred pounds per square inch the temperature would be 338 degrees, and if expanded four times, or twenty-five pounds, the terminal temperature would be 240, leaving the walls at this temperature, so that the incoming steam would again be robbed of some of its heat, to bring the temperature of the cylinder walls up again. In the figures given we find a difference of 98 degrees between the temperature of the steam when it first entered the cylinder and when the exhaust was about to take place; and the amount of heat absorbed by the wall to equalize the temperature is 49 degrees, which causes the condensation spoken of. This condensation is less as the steam follows the piston farther before cut-off takes place, or as the expansion is reduced.

In most compounds the steam is cut off at or near the end of the stroke in the high-pressure and then expanded in low-pressure cylinder.

Keeping the temperature nearly the same in the two cylinders, preventing excessive condensation.

The different systems are being pushed, and there are a great many two-cylinder compound engines running which give satisfaction. In a compound engine simplicity of construction is the main point looked at by some builders. The two-cylinder seems to meet that point. The difference in the two-cylinder compound engine is to be found in the construction of the intercepting-valve. Some work automatically, others work by hand.

The purpose of this valve is, in starting, to introduce live steam into the low-pressure cylinder and cut it off from that cylinder when under way. Some are made so that the engine can be run as a simple engine or compound, at will.

The difference between the four-cylinder engine and the two-cylinder, in handling the exhaust steam from the high to the low-pressure cylinder, is that in the two-cylinder the steam passes into a receiver or steam pipe in the front end or smoke-arch, and there the steam is reheated, as the receiver is exposed to the hot gases coming through the flues. This is a very good feature in a two-cylinder engine.

CHAPTER X.

INDICATOR-CARDS.

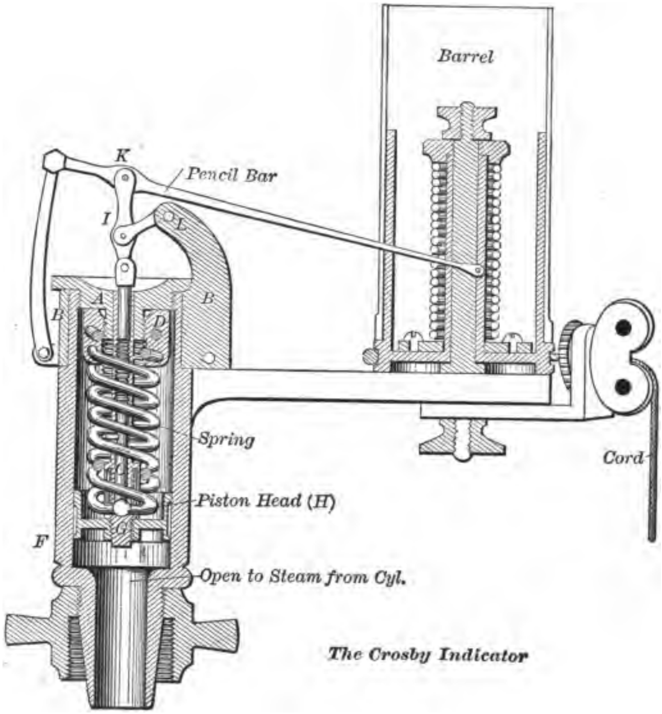
THE action of double-expansion in a compound engine is very simply shown by an indicator-card.

An indicator-card is traced on paper by a machine called an indicator, of which the construction is as follows (Fig. 45):

The main part consists of a cylinder, which is attached to the steam-cylinder of which cards are being taken.

In this small cylinder is a piston-head having a piston-rod. To the piston-rod is a pencil-bar, which carries the pencil which traces the card. A spring is on the top of the piston-head to counteract the steam-pressure underneath. The springs are of various tensions, dependent on the steam-pressure used in the cylinder. On the cylinder is attached a revolving barrel, which carries the paper on which the card is traced. This barrel takes its motion from a cord which is fastened to a reducer, the reducer being fastened to the cross-head of the engine. The card then moves the whole stroke of the piston-head in steam-cylinder.

We have given this plain description of the indicator in order to give the reader some idea of how a card is taken. There are some very good books on the indi-

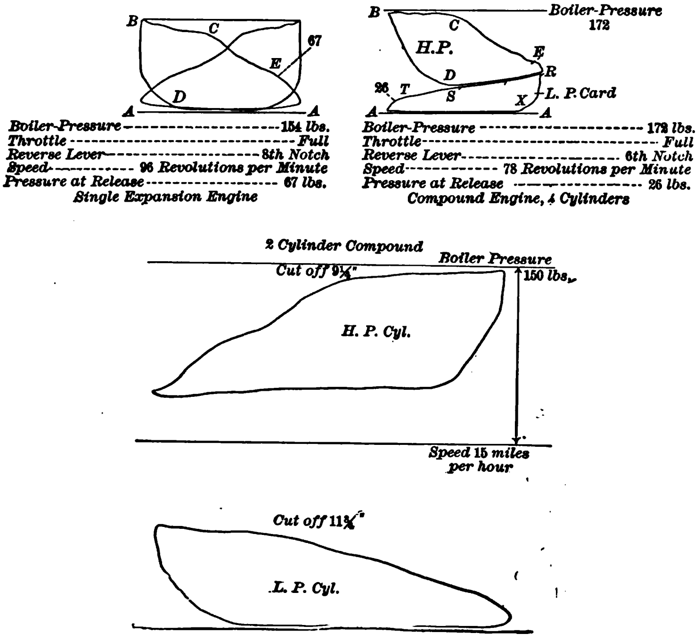


The Crosby Indicator

FIG. 45.

cator, such as "Twenty Years with the Indicator," by Thomas Pray, Jr., and others.

The indicator-card shows exactly the distribution and action of the steam in a cylinder, and is traced as in Fig. 46, which shows a compound card.



Boiler-Pressure------------------------154 *lbs.*
Throttle--------------------------------*Full*
Reverse Lever-----------------------8*th Notch*
Speed------------- 96 *Revolutions per Minute*
Pressure at Release------------------- 67 *lbs.*
Single Expansion Engine

Boiler-Pressure ------------------------ 172 *lbs.*
Throttle------------------------------------ *Full*
Reverse Lever------------------------- 6*th Notch*
Speed------------- 78 *Revolutions per Minute*
Pressure at Release ------------------ 26 *lbs.*
Compound Engine, 4 *Cylinders*

FIG. 46.

The straight line at *AA* is called the atmospheric line. With no steam in the cylinder the pencil would rest on the line *AA*, but when the steam-valve opens the pencil will be moved up to *B*, and as the valve remains open the pencil will trace the line from *B* to *C*, which is called the steam-line. When the valve closes at *C* then expansion begins, and continues to the point *E*; this is called the point of release. From *E* to *D* is the exhaust and back-pressure line. From *D* to *B* is the compression-line, the valve being closed to the exhaust.

This is the outline of the high-pressure card. There being an indicator on the low-pressure cylinder, the low-pressure card is traced also.

When the steam begins to exhaust from the high-pressure cylinder at *E* on high-pressure card, the low-pressure valve opens and the steam-line from *R* to *S* is traced, while the line from *E* to *D* is traced on the high-pressure card.

When the low-pressure valve closes at *S* the expansion in low-pressure cylinder takes place, as from *S* to *T*; then the exhaust begins, and continues until the valve closes at *X*. As will be seen, the steam has been expanded in two cylinders before exhausting into the atmosphere, and the terminal pressure in low-pressure cylinder is 26 lbs. The boiler-pressure was 172 lbs., and has been expanded down to 26 lbs. at the point of exhaust. In Fig. 46 is a card taken from a high-pressure or single-expansion, the boiler-pressure being 154 lbs., the speed being nearly the same for both engines; the terminal pressure is 67 lbs., which is a much higher terminal than the compound engine; also, the high-pressure engine has a much lower pressure. Then it is this high terminal pressure which the advocates of the compound engine claim is used as an additional power, instead of being exhausted out into the atmosphere as in the single engine, thereby reducing the amount of steam used to do a certain amount of work, and so saving fuel.

CHAPTER XI.

DESCRIPTION OF VARIOUS SYSTEMS OF COMPOUND LOCOMOTIVES.

THE VAUCLAIN OR BALDWIN SYSTEM.

IN designing the "Vauclain" or Baldwin system of compound locomotives, the following results have been sought:

1. To compound an ordinary locomotive with the fewest possible alterations necessary to obtain the greatest efficiency as a compound locomotive.

2. To develop the same amount of power on each side of the locomotive, and avoid the racking of the machinery resulting from uneven distribution of power.

3. To make a locomotive in every respect as efficient as a single-expansion engine of similar weight and type.

4. To insure the least possible difference in the cost of repairs.

5. To attain the utmost simplicity and freedom from complication.

6. To realize the maximum economy of fuel and water.

7. To require the least possible departure from the methods of handling usual with single-expansion locomotives.

8. To permit a train, in case of breakdown, to be brought in without unusual delay, when using but one side of the locomotive.

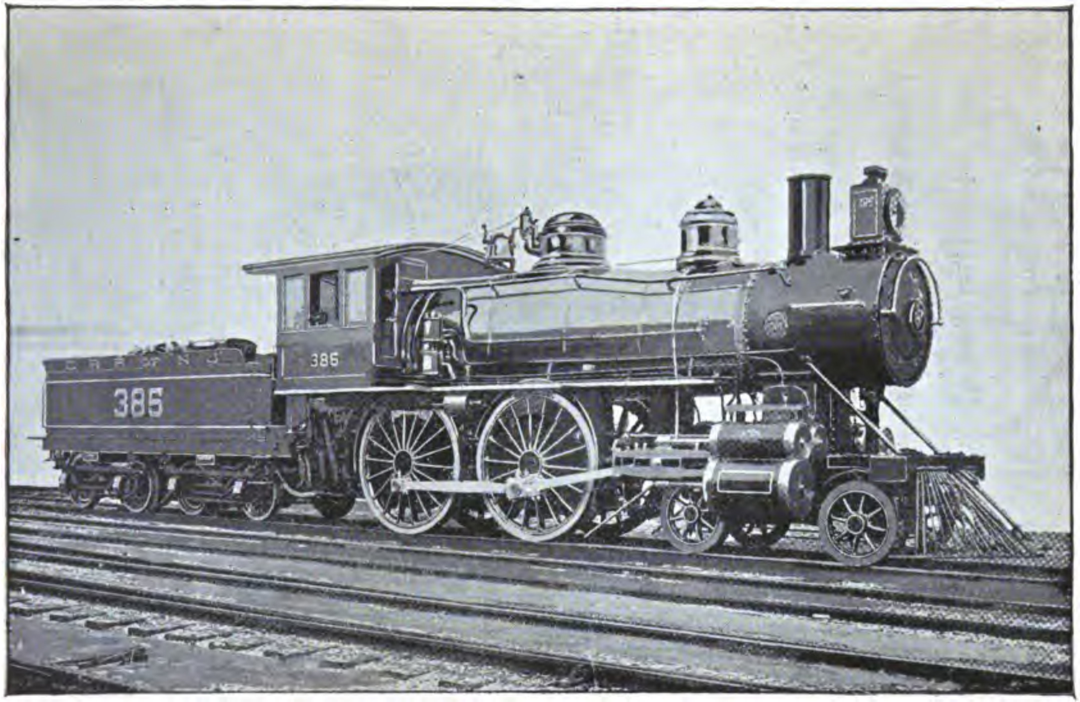


FIG. 47.—EIGHT-WHEELED "COMPOUND" LOCOMOTIVE.

Speed, 1 mile in 37 seconds.

H.-P. Cylinder, 13″ Diameter.
L.-P. Cylinder, 22″ Diameter.
Stroke, 24″.

Driving-wheels, 78″ Diameter.
Total Weight, 124,000 Pounds.
Weight on Drivers, 88,000 Pounds.

Total Wheel-base, 22′ 3½″.
Driving-wheel Base, 7′ 6″.

9. To be equally applicable to passenger and freight engines.

10. To withstand the rough usage incidental to ordinary railroad service.

The principal features of the construction are as follows:

The cylinders consist of one high-pressure and one low-pressure for each side, the ratio of the volumes being as nearly three to one as the employment of convenient measurement will allow. They are cast in one piece with the valve-chamber and saddle, the cylinders being in the same vertical plane, and as close together as they can be with adequate walls between them. Where the conditions, such as diameter of driving-

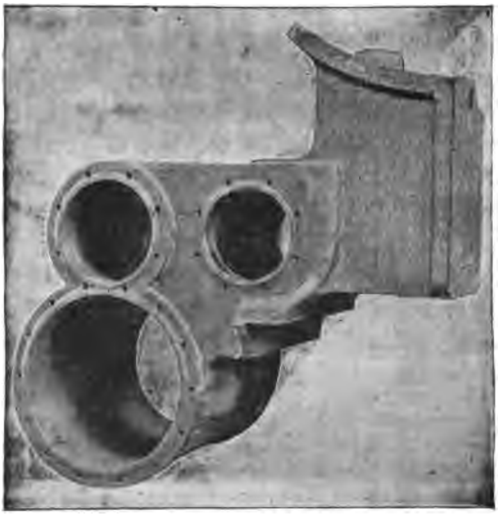


FIG. 48.—CYLINDERS FOR HIGH WHEELS.

wheels and type of engine, will allow, the high-pressure cylinder is put on top, Fig. 48; but where the wheels are low, the position is reversed, Fig. 49. This latter is the practice with consolidation and other engines, where the roadway clearance would interfere should the first position be used. The valve-chamber is placed in the cylinder-saddle between the boiler and cylinders.

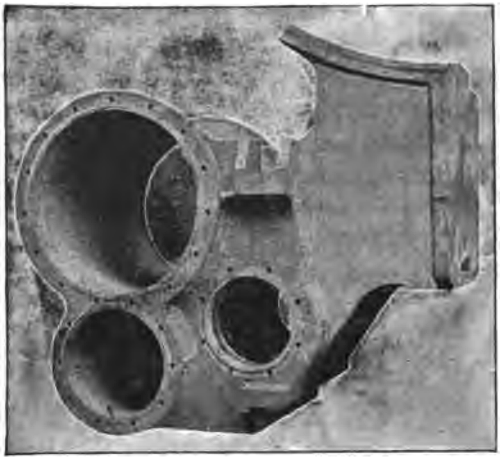


FIG. 49.—CYLINDERS FOR LOW WHEELS.

As the construction of this chamber is such that the steam-passage must be rough-cored, a bushing, in which the ports are accurately slotted, is turned to a neat fit and forced into the valve-chamber. The ports in the bushing are divided at regular intervals by bridges, as shown in Fig. 50. The valve shown by Fig. 51 is of the hollow-piston type, fitted with cast-iron rings sprung into place, after the manner of the ordinary piston-rings.

It is a combination of two D valves in piston form, the two ends of which control the admission and exhaust of steam to and from the high-pressure cylinder, and the inner rings perform the same functions for the low-pressure cylinder.

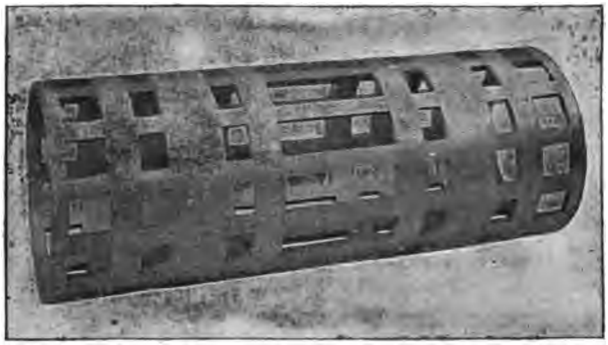


FIG. 50.

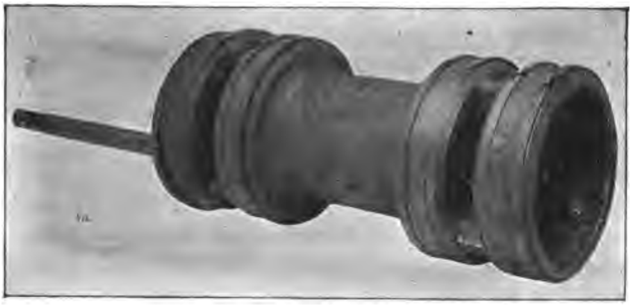


FIG. 51.

Its operation will be clearly understood by Fig. 52. When the low-pressure piston is placed on top, the position of the valve is such as to preclude the use of the common rocker-box. Case-hardened cross-head and guides are substituted, and operated in direct motion from the links by means of an extension-bar.

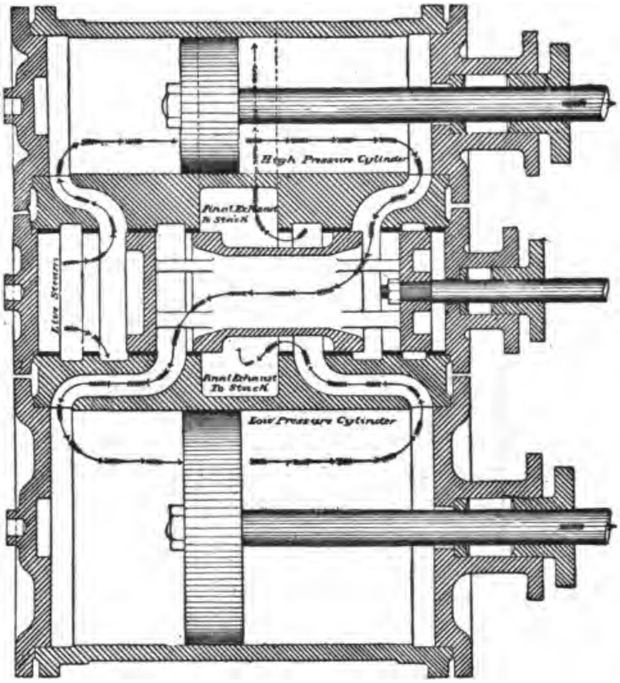


FIG. 52.—DIAGRAM OF THE BALDWIN PATENT COMPOUND CYLINDER AND PISTON SLIDE-VALVE, SHOWING THE COURSE OF THE STEAM.

In this manner the wear is reduced to a minimum, and all parts are made easy of access.

The cross-head, which is shown in Fig. 53, is of cast steel, of a pattern combining great strength with the least possible metal.

The wearing-surfaces are covered with block-tin one-sixteenth inch thick. The piston-rods are of the same size for both high-pressure and low-pressure piston. This is to secure uniformity of parts, ease in fitting up, and to make it unnecessary to carry more than one size of piston-rod packing in stock. The low-pressure pistons and rods are so proportioned that in case an excess of pressure is by accident admitted to the low-pressure cylinder they will withstand the strain with an adequate factor of safety.

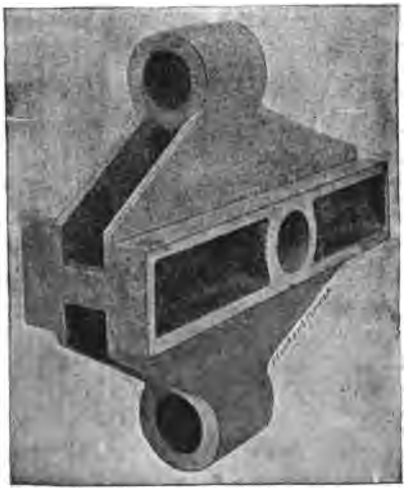


FIG. 53.

The starting-valve of the Baldwin Compound is simple in construction, but the action is hardly understood by a great many handling the engine. The operation is as follows:

When the valve is put in position for starting, live steam passes from that end of high-pressure cylinder in which main-valve is admitting live-steam, through the starting-valve to the other end of high-pressure cylinder—bear in mind that the steam-port on this end of high-pressure cylinder is open to the low-pressure steam-port — through the main-valve, which is the course the exhaust-steam would take, Fig. 52. The live-steam would follow this same course, exerting its power against the low-pressure piston, and at the same time, at slow speed, put the high-pressure piston-head in nearly an equilibrium.

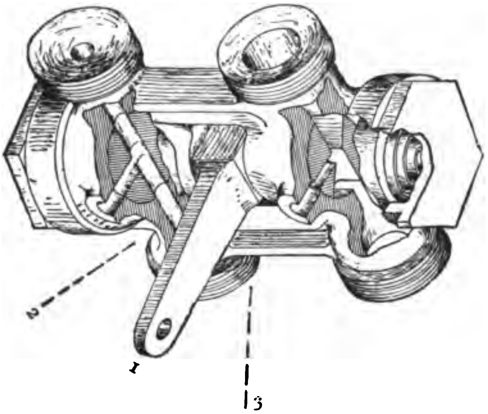


FIG. 54.—COMBINED CYLINDER-COCK AND STARTING-VALVE FOR VAUCLAIN COMPOUND LOCOMOTIVE.

But the amount of steam that enters the low-pressure cylinder through the starting-valve decreases as the speed increases. The combined starting-valve and cylinder-cock, Fig. 54, consists of a single casting, in which there are two taper-plugs, one controlling the high-pressure cylinder-cock and the steam for starting, the other controlling the low-pressure cylinder-cock.

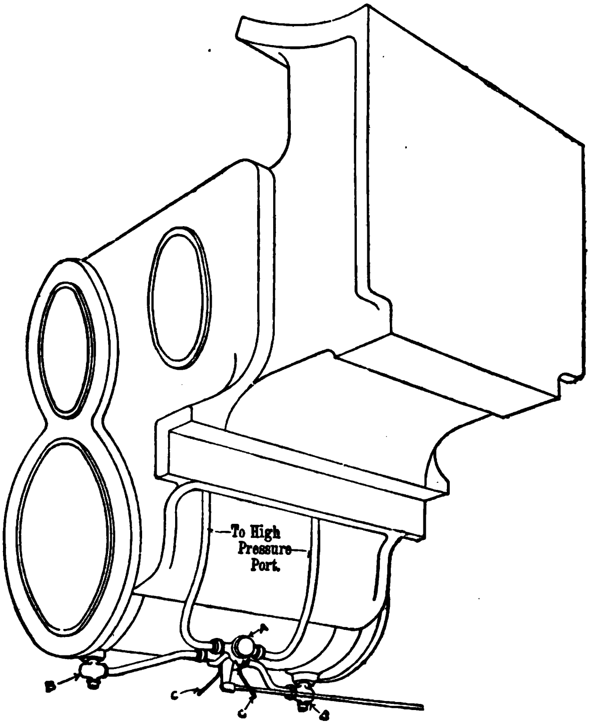


FIG. 55.—COMBINED STARTING-VALVE AND CYLINDER-COCK FOR COMPOUND LOCOMOTIVE.

The two plugs are held in place by springs, and controlled by an arm operated by a lever in cab. The operation is as follows:

In position 1 the starting-valve is open to admit live steam to the low-pressure cylinder, the cylinder-cocks at the same time being open to the atmosphere.

In position 2 all passages are closed.

In position 3 the starting-valve only is open to admit live steam to low-pressure cylinder. Fig. 55 shows the application. Air-valves to relieve the vacuum in the low-pressure cylinders when the engine is running with steam shut off are placed in each end of the low-pressure cylinders, where cylinder-cocks are ordinarily located. *BB*, Fig. 55.

The combination cylinder-cock and by-pass valve, Fig. 56,* is designed to take the place of independent cylinder-cocks and by-pass valve for each cylinder, so the whole may be operated by a single lever in the cab.

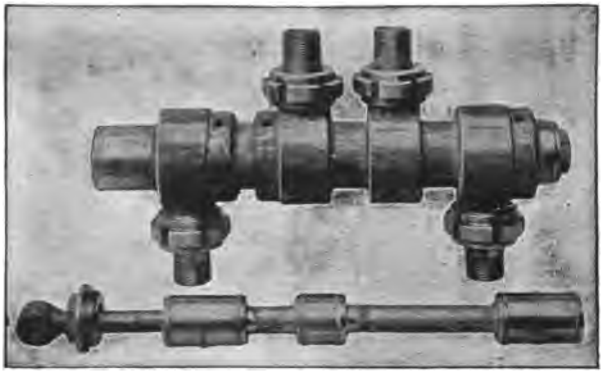


FIG. 56.

The construction of this valve is such that by a simple movement of the lever the cylinder-cocks may be opened or closed and at the same time admit live steam into the low-pressure cylinder, when needed to start a train ; or the cylinder-cocks may be closed, the live steam cut off from the low-pressure cylinder, and the engine will be compounding in the most economical manner. The valve consists of a cylinder having a connection to each end of the high- and low-pressure cylinders, in which works a plunger with three piston-heads fitted with packing-rings. These piston-heads

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* Old style.

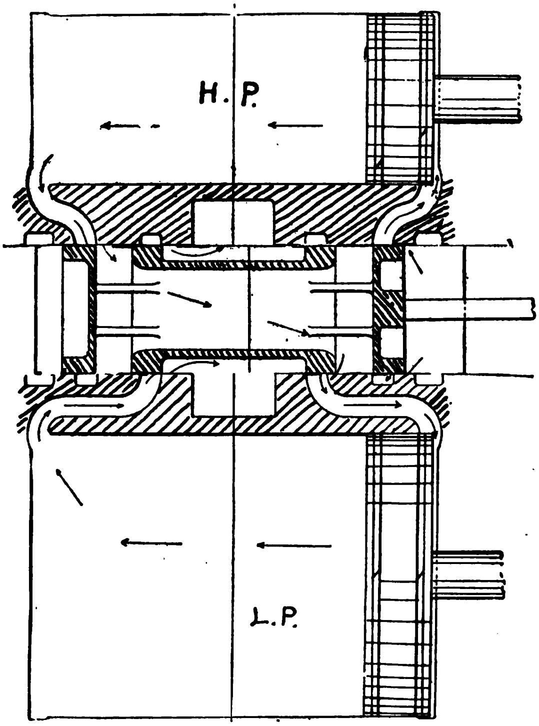

FIG. 57.

are so spaced that by a change of their position in the cylinders the desired results described above are obtained. These are the only points of difference between a Vauclain compound and a single-expansion locomotive. The compound is operated the same as an ordinary engine, with the exception of the by-pass or intercepting valve, which is used only in starting to admit high-pressure steam to the low-pressure cylinders.

ACCIDENTS WITH THE BALDWIN COMPOUND.

When a main steam valve-rod on a Baldwin Compound is broken or disconnected, what must be done in order to bring the engine in?

The valve must be put in the centre of the seat, covering all the ports on that side. Take down main-rod and block cross-head as for a simple engine. (See Fig. 57 for position of valve.) This rule applies for both engines, as they are the same in construction.

Can a Baldwin Compound be run with both sides if a low-pressure cylinder-head is broken out?

The engine can be run with a low-pressure cylinder-head broken out with both sides without disconnecting.

What would be the course of the steam on the broken side?

The steam from one end of the high-pressure cylinder would pass into low-pressure cylinder, and from there into the stack; but from that on which head is broken out the steam would pass out into the atmosphere through open end of cylinder.

Would it be policy to disconnect in a case of this kind?

It would, on account of the escaping steam interrupting the view of the engineer, if far to go, when broken on his side. But when the piston-head breaks from the cross-head, goes out of the cylinder, the steam escapes from both ends of high-pressure cylinder into atmosphere through open ends of low-pressure cylinder.

Has a Baldwin compound ever been run with both low-pressure cylinder-heads broken out?

They have been run for some distance this way.

How many exhausts is there on the fire running with both low-pressure cylinder-heads broken out?

Only two per revolution.

Can a Baldwin Compound be run with the high-pressure piston-heads taken out of cylinders?

The engine can be run in this manner by putting a board or washer across the stuffing-box, bolting it fast. This will make it steam-tight. The steam-valve will supply steam to the low-pressure cylinder.

What would be the course of the steam?

The steam would enter the high-pressure cylinders, pass from there through the main steam-valves into the low-pressure cylinders, these cylinders acting as a high-pressure engine.

When a main-rod breaks or is disconnected, what should be done?

The valve put in centre of seat on that side covering all ports blocking cross-head; run with the other side.

On engines using the direct motion for the valves, the end of valve steam is carried on cross-head, sliding between guides.

What is a good way to fasten the valve?

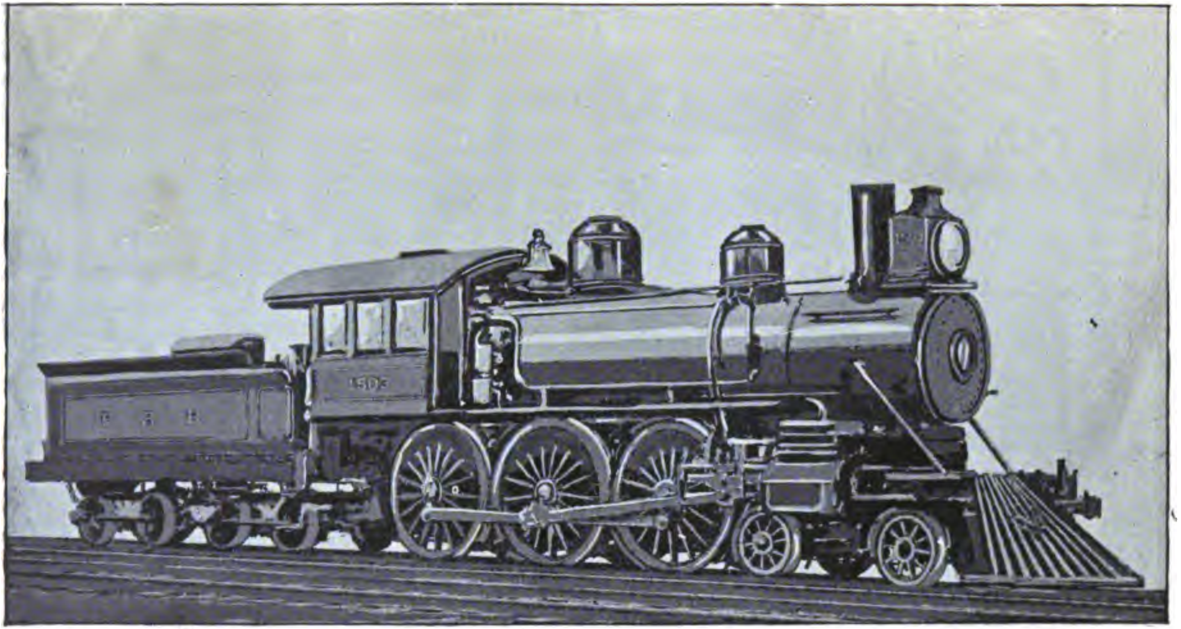

FIG. 58.—TWO-CYLINDER COMPOUND PASSENGER LOCOMOTIVE FOR THE PENNSYLVANIA RAILROAD. BUILT BY THE SCHENECTADY LOCOMOTIVE WORKS, SCHENECTADY N. Y.

Cylinders H.P., 20×24.
Cylinders L.P., 30×24.
Driving-wheels 74″.

Total Weight, 138,000 pounds.
On Drivers, 102,000 pounds.
Boiler Diameter, 58″.

Fire-box $96\frac{3}{16}$ long.
" $39\frac{1}{4}$ wide.
Pressure, 180 pounds.

Put the valve in centre of seat, and put blocks each side of small cross-head.

If the small equalizing-valve in the end of main steam-valve is broken or taken out, would it interfere with the working of the engine on that side?

It would convert that side into a high-pressure engine. The work would be done by the low-pressure cylinder, the high-pressure piston would be nearly balanced; this would occur also when a head was broken out of the main steam-valve.

When running along and not using steam, always open the cylinder-cocks; this will prevent the low-pressure piston from creating a vacuum in high-pressure cylinder, and causing the packing to be picked up by the high-pressure piston-rod; this is injurious to the packings, when the engine is equipped with old style of starting-valve. (See Fig. 56.)

THE SCHENECTADY COMPOUND LOCOMOTIVE.

Probably the most interesting feature of this engine is the new starting gear and intercepting-valve apparatus, invented by Mr. A. J. Pitkin, Superintendent of the Schenectady Locomotive Works. This we show in considerable detail. Figs. 59 and 61 show the intercepting-valve open; that is, in the position before the engine starts. Fig. 60 shows the intercepting-valve closed, or in the position at the time of the initial movement.

The construction of this valve is as follows (see Figs. 59, 60, and 61):

There are two pistons *A A* at one end of the single stem *B*, which moves to and fro in a cylindrical chamber having three openings. Two of these openings,

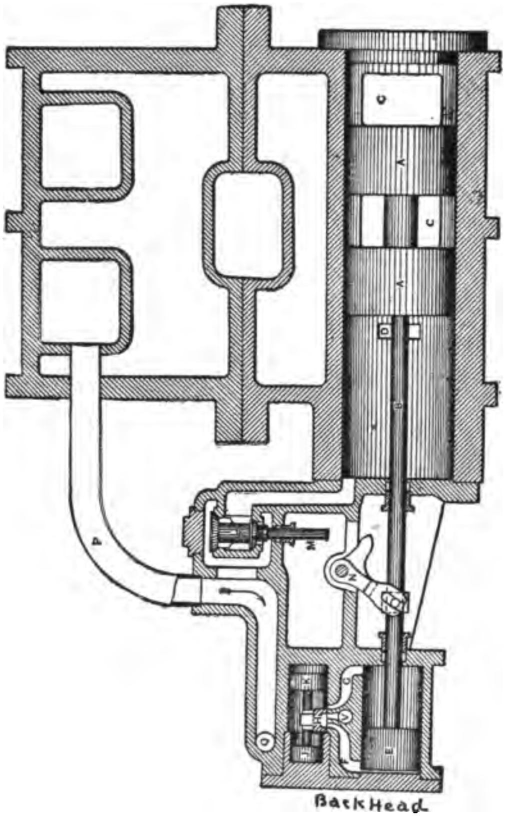

FIG. 59.

C C, lead to the receiver and to the low-pressure steam-chest, as shown in Fig. 59, and it is the office of the pistons *A A* to open and close these large openings and prevent the steam in the low-pressure steam-chest from entering the receiver when it is not wanted there. The other opening, *D*, in this cylinder (see Figs. 59 and 60) connects the intercepting-valve cylinder with the low-pressure steam-chest.

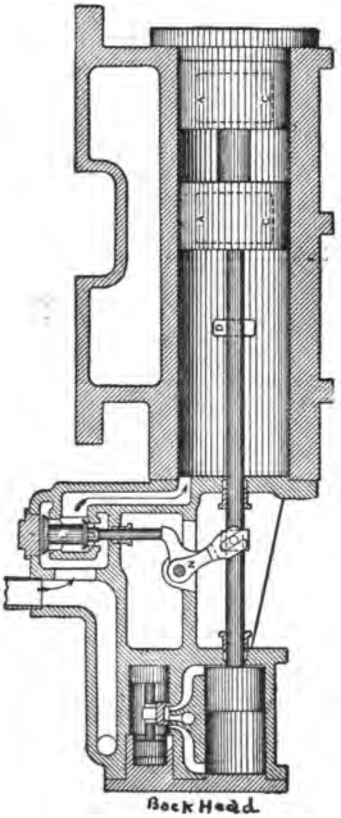

FIG. 60.

So far we have described the intercepting-valve proper. The remaining portion of the mechanism is the apparatus for driving and connecting the intercepting-valve. It is constructed as follows:

On the end of the stem *B*, which passes through a stuffing-box in the end of the intercepting-valve chamber, there is a piston *E*, which moves in a small cylinder having ports *F* and *G*, one at each end. These ports lead to a valve-seat, on which is a plain D valve

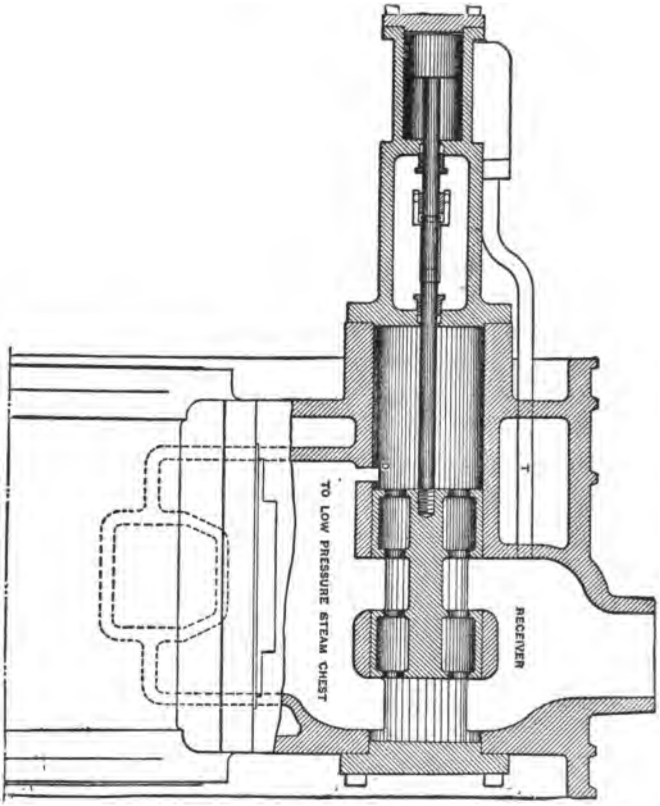

FIG. 61.

not unlike the ordinary locomotive slide-valve. This slide-valve is moved to and fro by means of a double piston with a stem between, shown at *J* and *K*. These pistons are of different diameter, *K* being larger than *J*, and as they move to and fro they carry with them the slide-valve. The office of this portion of the mechanism is to move the intercepting-valve *AA* to and fro, as desired.

The third part of the device consists of a balance poppet-valve *L*, which is placed in the path of steam coming direct from the boiler to the low-pressure cylinder to assist in starting. This valve has an extended spindle *M* on the lower side, and is lifted by means of a bell-crank *N*, which is driven by means of a trunnion on the intercepting-valve stem *B*. As the stem *B* passes to the right the valve *L* is lifted, and as it passes to the left the valve *L* is allowed to fall. Fig. 62 is a detail of the pipe connections and passages leading to the pistons *J K*, the office of which will be described in what follows. Fig. 63 shows the location of the intercepting-valve and its parts in relation to the cylinders and steam-pipes. Fig. 64 is a section through the slide-valve *H*, showing that it has a cylindrical seat. The operation of this valve is follows:

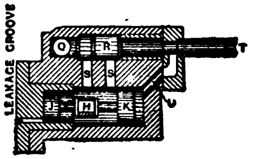

FIG. 62.

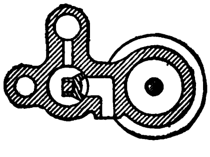

FIG. 64.

The engineer opens the throttle as usual. Steam passes into the high-pressure steam-pipe *O*, Fig. 63, and passes through the pipe *P*, which is tapped into the side of the saddle to the apparatus which actuates the intercepting-valve, as shown in Figs. 59 and 62. It passes down through the passage *Q*, through the small ports *S S*, between the pistons *J* and *K*. *K* being larger

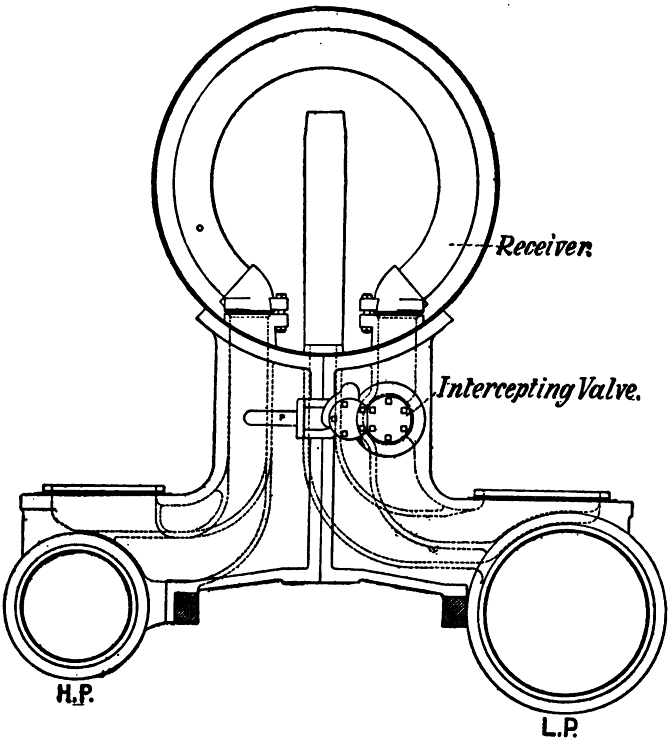

FIG. 63.

than *J*, it has a greater total pressure; hence the pistons move to the right and carry the slide-valve with them. This opens the port *F*, and allows the steam to pass on the left side of the piston *E*, and forces it, together with the intercepting-valve *A A*, to the right until it is in the position shown in Fig. 60, with the *C C* passages closed. The position of the pistons *J K* and the slide-valve *H* at this time are shown in Fig. 60.

During the foregoing operation, as the intercepting-valve stem *B* moves to the right it carries with it the bell-crank to the position shown in Fig. 60, thus lifting the balance poppet-valve *L*, and admitting steam, as shown by the arrows, Fig. 60, into the intercepting-valve cylinder, from whence it passes out through the opening *D* into the low-pressure cylinder steam-chest, and in this way steam is admitted direct from the boiler to the low-pressure steam-chest always just before the engine starts.

As soon as the engine has started, and there is an exhaust into the receiver from the high-pressure cylinder, steam passes from the receiver through the pipe *T*, shown in Fig. 61, to the passages leading to the small slide-valve *H*, as shown in Fig. 62. This pressure acting on the right-hand side of the larger piston *K*, through the smaller passage *U*, overcomes the pressure on the other side of this piston *K*, and the pistons *J* and *K* move to the left, carrying the slide-valve *H* with them. This movement opens the steam-passage *G*, Fig. 59, and the exhaust-passage *V*, and admits steam to the right side of the piston *E*, and drives it to the left, and with it the intercepting-valves *A*, thus opening the passages *C* and the receiver to the low-pressure steam-chest. At the same time the bell-crank *N* is moved to the left, and the valve *L* is allowed to drop into the position shows in Fig. 59, thus cutting off the connection between the boiler and the low-pressure steam-chest.

After this the engine works in the well-known way of the two-cylinder compound, that is, by taking steam into the high-pressure cylinder, discharging it into the receiver, taking it out of the receiver into the low-pressure cylinder, and discharging it into the atmosphere.

ACCIDENTS WITH THE SCHENECTADY COMPOUND LOCOMOTIVE AND INTERCEPTING-VALVE.

When a main rod of the high-pressure engine is broken or disconnected, what should be done to bring the engine in or continue the trip?

The high-pressure valve should be moved ahead to clear exhaust-port, and the piston pushed in the forward end of cylinder and blocked. The live steam would pass through the exhaust-port on the high-pressure side into the receiver, from there into the low-pressure steam-chest. The low-pressure cylinder would then be acting as a high-pressure engine. Care must be taken not to open the throttle-valve suddenly, on account of the large area of low-pressure cylinder.

When the low-pressure main-rod is broken or disconnected, what should be done?

The piston-head must be blocked in the back end of the cylinder, and the low-pressure valve moved back to clear the exhaust-port on that side, the valve covering the back-port when a head is not broken out. Opening the exhaust-port on the low-pressure side provides an outlet for the exhaust-steam from high-pressure engine.

Why must the high-pressure valve be pushed ahead?

In order to clear the receiving-port, or the port by which the live steam enters the high-pressure steam-chest, this port being in the back end of the steam-chest.

When a valve-rod breaks on either side, what should be done?

Do the same as for a broken main-rod on that side; also, take down the main-rod and block cross-head.

If the back-head of intercepting-valve steam-cylinder broke out, could the engine be run as a compound engine?

The engine would be as a compound engine, from the fact that the intercepting-valve would not be moved to the position as when starting as a non-compound because of the steam in the intercepting-valve cylinder not being able to move the valve to the proper position on account of the head being broken out; also, the exhaust from the high-pressure cylinder into receiver would hold the intercepting-valve in the compounding position.

Would steam escape from the steam-cylinder of intercepting-valve in this case when in the compounding position?

Steam would not escape when in this position. The engineer should see that the lever in cab is in the proper position for compounding. When the lever is put in the position for starting, then steam would escape from the back end of steam-cylinder of intercepting-valve with the head broken out.

Has this ever happened?

It has.

How would it be possible to use live steam in both cylinders when starting with the intercepting-valve disabled in the manner spoken of?

Live steam could be used in both cylinders to start with by lifting the poppet-valve and blocking it from the seat. This would let live steam into the low-pressure steam-chest.

When should this be done?

Before the throttle is opened.

Would it be possible to run with low-pressure cylinder having the high-pressure valve covering all the ports on H. P. side?

The engine can be run in this manner. With the intercepting poppet-valves steam will pass through the poppet-valve into the low-pressure steam-chest. The engineer must put the lever in cab in the position for starting. This will admit steam into back end of intercepting-valve steam-cylinder, closing the receiver and holding poppet-valve open. As there is no steam in the receiver, the intercepting-valve will not open and close the poppet-valve.

Is there any other way in which the poppet-valve could be held open to admit live steam into the low-pressure steam-chest?

The poppet-valve could be held open by taking the back head off the intercepting-valve steam-cylinder and pushing the piston-head in forward end of cylinder and putting a block in, and putting on the head, This would prevent the steam in receiver from closing the poppet-valve. The same can be done with the small piston moving the valve admitting steam to the intercepting-valve steam-cylinder. This will also prevent the movement of the intercepting-valve mechanism and closing the poppet-valve.

What form of breakdown would cause the high-pressure valve to be put in the position to cover all the ports on that side?

When both cylinder-heads are broken out or a front head broken out, and a piece broken out of the bridge between exhaust-port and front steam-port; also, it is policy when running with low-pressure cylinder alone, and do not want any steam to get into the high-pressure cylinder, to cover all the ports on the high-pressure side.

How can the engine be used as a high-pressure engine for some distance when starting?

By shifting the lever in and out of compound position repeatedly. Remember that there is no steam in the intercepting-valve when the throttle is closed and the dry-pipe empty. Disconnect as for a simple engine for other breaks.

COMPOUND PASSENGER LOCOMOTIVE, NEW YORK, NEW HAVEN & HARTFORD R. R.*

The line and photo engravings on the opposite page show the general appearance and some details of construction of a new eight-wheeled compound locomo-

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* Nat. Car and Loco. Builder,

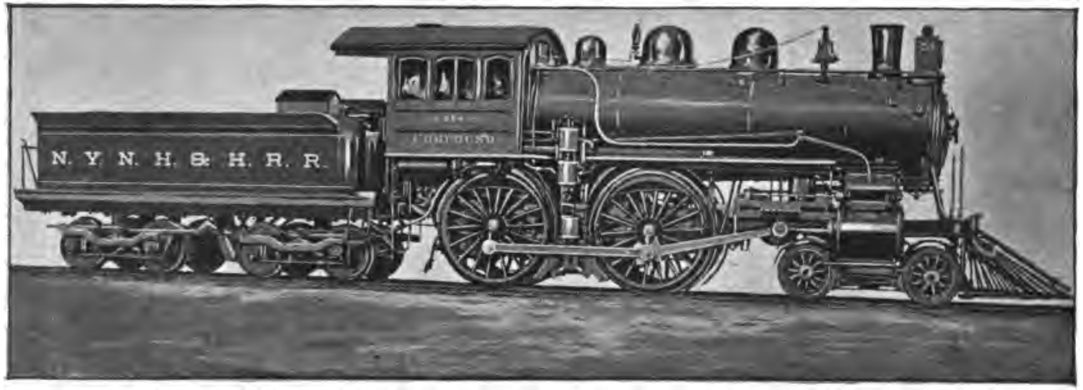


FIG. 65.—COMPOUND PASSENGER LOCOMOTIVE.

Cylinders, 21"×31"×26".
Driving-wheels, 78" Diameter.
Truck-wheels, 33" Diameter.
Total Wheel-base, 22′ 9".

Total Weight Working Order, 125,000 Pounds.
Total Weight on Drivers, 84,000 pounds.

Boiler, 60" Diameter.
Flues, 250.
Fire-box, 120×41½.
Steam-pressure, 200 pounds.

tive built for the New York, New Haven & Hartford Railroad, according to designs furnished by Mr. John Henney, Jr., Superintendent of Motive Power, by the Rhode Island Locomotive Works.

The intercepting-valve is the Rhode Island Locomotive Works patent.

Figs. 66 and 67 illustrate the construction and show the operation of the intercepting-valve. Fig. 66 shows a front section of the intercepting-valve at ports *d* and *e*; also a view of a portion of receiver with the exhaust-valve. Fig. 67 shows a side section of intercepting-valve while running compound, and Fig. 68 shows same while running simple. *A* (in Figs. 65, 66, and 67) is the intercepting-valve casing. *B* is the reducing-valve. *C* (in Fig. 67) is the oil dashpot. *D* (in Figs. 65 and 66) is a pipe from main steam-pipe to intercepting-valve. *E* is the receiver, and *F* is the exhaust-valve; *a*, *b*, and *c* (in Figs. 67 and 68) show the intercepting-valve pistons; *d*, port from *D*, through *A*; *e*, port from *A* into the reducing-valve *B*; *f* (in Figs. 67 and 68), port from *A* into passage to low-pressure steam-chest; *m*, exhaust-valve lever; and *o*, ports through exhaust-valve and seat.

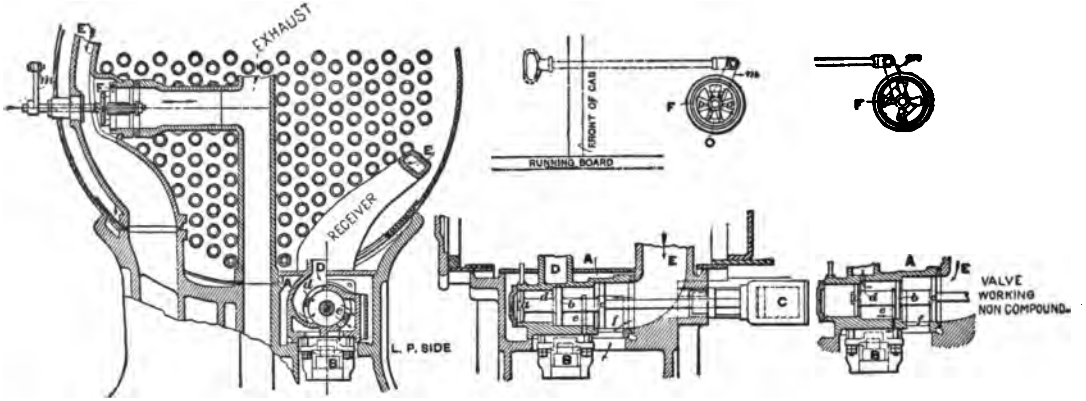
This device operates as follows, the intercepting-valve being in any position (as in Fig. 67), and the exhaust-valve closed (as in Fig. 67) and the throttle open:

Boiler-steam will pass to the high-pressure cylinder, in the usual manner, and also through pipe *D* into the intercepting-valve *A*, causing the piston to move into the position shown in Fig. 68. In this position the receiver is closed to the low-pressure cylinder by the piston *C*, and steam from *D* passes through ports *d* and *e* and reducing-valve *B* into the low-pressure steam-chest, the pressure being reduced from boiler-pressure, in the ratio of the cylinder areas. The piston *a*, *b*, *c* is so proportioned that it will automatically change to the compound position shown in Fig. 67, when a predetermined pressure in the receiver *E* has been reached by exhausts from the high-pressure cylinder. The engine thus starts with steam in both cylinders, and automatically changes to compound at a desired receiver-pressure.

The engine may be changed from the compound system to the simple at any time, at the will of the engineer, by opening the valve *F* connecting the receiver to the exhaust-pipe, allowing the exhausts from the high-pressure cylinder to escape through the nozzle in the usual manner.

The exhaust-valve *F* is operated as follows: The lever *m*, which rotates the exhaust-valve *F*, is connected by a rod to a handle in cab. To run compound, place lever *m*, as shown in Fig. 67, which closes ports *o*. To run simple, place lever *m*, as shown in Fig. 68, the ports *o* opening *E* to exhaust.

It is obvious that, in case of bad conditions of starting, the engine may be operated as a simple one at the will of the engineer by opening the exhaust-valve before starting, and that upon its closure the piston *a*, *b*, *c* will automatically take the compound position shown in Fig. 67.



COMPOUND

FIG. 66. FIG. 67. FIG. 68.

INTERCEPTING-VALVE FOR COMPOUND ENGINES.

ACCIDENTS WITH THE RHODE ISLAND COMPOUND AND INTERCEPTING-VALVE.

When a valve-rod of the low-pressure engine is broken or disconnected, how should the engine be prepared to be brought in?

The valve on low-pressure side should be put in the centre of the seat covering the ports on that side, then open the exhaust-valve in receiver to exhaust-nozzle; run with the high-pressure engine disconnected main as for simple engine on low-pressure side.

Why does not the live steam from the reducing-valve escape into the receiver and from there into the atmosphere?

On account of the receiver having no pressure in it, the intercepting-valve remains closed to the receiver, holding the live steam in the low-pressure steam-chest.

When a main-rod is broken or disconnected on the low-pressure side, what must be done?

Do the same as for a broken valve-rod.

When a valve-rod is broken or a main-rod must be taken down on the high-pressure side, what should be done in this case to bring the engine in?

The steam-valve on high-pressure side should be put in the centre of the seat covering the ports, and run with low-pressure side.

How does the live steam get into the low-pressure steam-chest?

Through the reducing and intercepting valve, the latter valve confining the steam within the low-pressure steam-chest.

If the piston-head of intercepting-valve that closes the receiver to low-pressure steam-chest should be broken or cracked, how could the engine be run without using in the low-pressure cylinder live steam, or having an excessive back-pressure on high-pressure piston-head?

By taking off the back-head of the intercepting-valve oil-cylinder, and putting a block in, pushing the intercepting-valve to the position for compounding, putting on the cylinder-head, and screwing tight against the block.

Why cannot the exhaust-valve in receiver be opened and the engine run as a high-pressure engine?

On account of the hole in intercepting-valve letting the live steam escape into the atmosphere from the low-pressure steam-chest.

What would be the effect if the middle piston-head of intercepting-valve was cracked or broken out?

The live steam would move intercepting-valve to the non-compound position, closing the receiver, and admitting live steam to the low-pressure cylinder. This would form a heavy back-pressure against the high-pressure piston-head.

What should be done then to overcome this back-pressure?

Open the exhaust-valve in receiver and run as a high-pressure engine. The intercepting-valve must be closed in this case, or live steam will pass out into the exhaust-pipe through the receiver.

How should the engine be run with a broken or cracked receiver?

By opening the exhaust in receiver and running as a high-pressure engine.

Disconnect for other breaks as for a simple engine.

A COMPOUND PASSENGER LOCOMOTIVE.

The accompanying illustration is from a photograph of an 8-wheel compound engine recently built by the Pittsburgh Locomotive Works. It is of the two-cylinder type, and has the starting-valve patented by Mr. Henry F. Colvin of Philadelphia. With this the engine can be worked as a compound, or steam can be admitted directly into the low-pressure cylinder at the will of the engineer. In the latter case the valve admitting steam from the boiler acts as a reducing-valve, in order to equalize the force exerted in the two cylinders.

Figs. 70 and 71 show the general construction of the starting gear and intercepting-valve of the Pittsburgh compound locomotives. This gear is generally placed on the cylinder saddle, and is so arranged that the engineer, by moving the lever in the cab, can open an independent exhaust for the high-pressure cylinder through the passage, Fig. 71, to the stack. When it is desired to run compound the lever is again moved and the intercepting-valve is open. In Fig. 70 the intercepting and reducing valves are shown when in the position to work compound.

In this system steam from the steam-pipe in the high-pressure cylinder saddle passes to the reducing-valve through a small passage shown in Figs. 70 and 71. When the reducing-valve is permitted to open, as it is

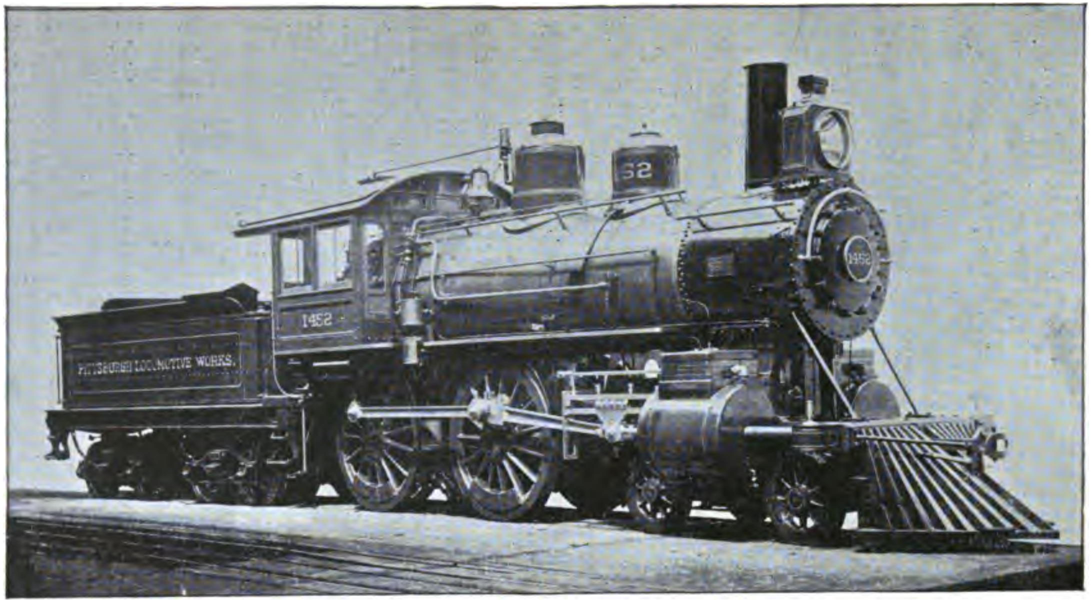


FIG. 68.—EIGHT-WHEEL COMPOUND PASSENGER ENGINE, BUILT BY THE PITTSBURGH LOCOMOTIVE WORKS.

Gauge of Road, 4 feet 8½ inches.
Cylinders, 19 and 29×26 inches.
Total Wheel-base, 22 feet 6 inches.
Driving-wheel Base, 8 feet.
Diameter of Driving-wheels, 72 inches.
Total Weight, 112,550 pounds.
Weight on Driving-wheels, 72,000 pounds.

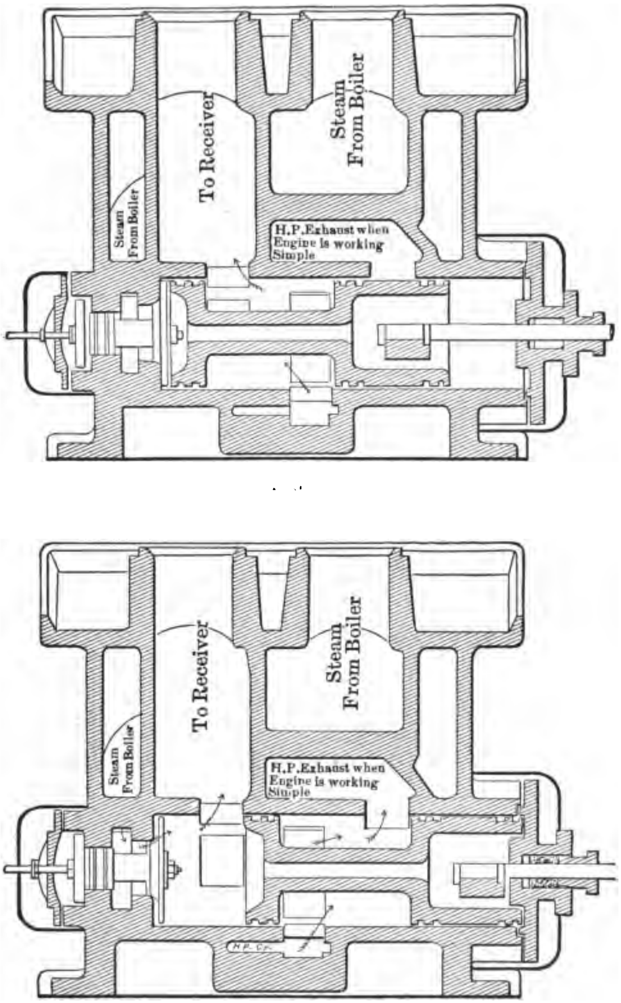

Steam From Boiler
To Receiver
Steam From Boiler
H.P. Exhaust when Engine is working Simple
Steam From Boiler
To Receiver
Steam From Boiler
H.P. Exhaust when Engine is working Simple
H.P. Cyl.

FIG. 71

in Fig. 71 by the removal of the intercepting-valve to the right, steam passes directly through the reducing-valve, as shown by the arrows from the high-pressure steam-pipe to the receiver, thence to the low-pressure cylinder. The amount of reduction of pressure by the reducing-valve depends upon the ratio of the areas of the piston of the reducing-valve and the area of the valve itself.

When the engine is to be run compound the engineer forces the intercepting-valve back to the position shown in Fig. 70 by means of the rod which is connected to a lever in the cab. The movement of the intercepting-valve to the left forces the reducing-valve to its seat, as shown in Fig. 70, and permits the high-pressure cylinder to exhaust into the receiver. When in the non-compound position, shown in Fig. 71, the high-pressure cylinder exhausts directly to the atmosphere, as indicated.

ACCIDENTS TO PITTSBURGH COMPOUND LOCOMOTIVE AND INTERCEPTING VALVE.

When a main-rod is broken or disconnected on the low-pressure side, what should be done to run engine to end of trip?

The low-pressure steam-valve must be put in centre of seat covering the ports on that side, the intercepting-valve pulled back-opening the exhaust from high-pressure cylinder to the stack; run in with high-pressure side.

When a valve-rod is broken or taken down on low-pressure side, what should be done in this case?

Do same as for a broken main-rod, also blocking cross-head and taking down main-rod, and run in with high-pressure side.

When the intercepting-valve is pulled back, opening the high-pressure to stack, does live steam get into the low-pressure steam-chest?

Steam passes through the reducing-valve into receiver and low-pressure steam-chest.

When a main-valve stem or rod is broken or taken down on the high pressure side, what should be done in order to bring the engine in?

The steam-valve on that side should be put in centre of seat covering the ports, the intercepting-valve pulled back, which opens the reducing-valve, admitting live steam into receiver and low-pressure steam-chest, do the same for a broken main-rod, and run in with low-pressure side.

If the reducing-valve was broken or a piece broken out, would it interfere with the working of the engine?

No. The engine can be run as a high-pressure engine, putting the intercepting-valve in the position as a non-compound, but the engine can be run as a compound by putting the intercepting-valve in the compounding position. The end or head of intercepting-valve has rings sprung in it; this will prevent the live steam from getting into receiver or low-pressure steam-chest.

If the front head of intercepting-valve was broken or cracked, what would be the effect on the engine when starting?

If the intercepting-valve was put in the non-compound position, as when starting or running as a high-pressure engine, the live steam escapes into the atmosphere, causing the engine to be weak on that side.

Can the engine be used as a high-pressure engine to start with in this condition?

If the break or crack is large enough, the intercepting-valve can be pushed ahead until the back-head covers the exhaust-port to stack. This will permit the live steam from reducing-valve to pass over into low-pressure steam-chest through the receiver. The intercepting-valve after a couple of revolutions of driver can be put in the compounding position closing the reducing-valve, and the engine run as a compound.

When a piece is broken out of front end of back-head of intercepting-valve, can the engine be run with both sides?

The engine can be run by putting intercepting-valve in the compound position, although the power of low-pressure cylinder would be reduced in proportion to the amount of steam escaping into stack through broken head.

How can the engine be run as a high-pressure engine when a piece is broken out of back-head of intercepting-valve?

By putting the valve in the non-compound position, and, driving a plug in the port leading from end of valve to the other. (The purpose of the port is to equalize the pressure on valve, so that it can be moved by hand.)

If the receiver was broken or cracked very badly, what should be done in this case?

The reducing-valve bound to its seat, the intercepting-valve put in the non-compound position, the low-pressure side disconnected as for a broken main-rod, run with the high-pressure side.

How can the reducing-valve be held to the seat when the intercepting-valve is away from it?

By taking off the collar on the end of reducing-valve and putting thick washers on; then put collar on and screw up tight-binding reducing-valve to seat.

What effect has a receiver which is very badly cracked or broken on the engine?

It destroys the draught, preventing the engine from steaming, and is liable to cause a back draught and burn the fireman.

This applies to any engine using a receiver in front end.

Disconnect as for a simple engine for other breaks.

THE BROOKS TWO-CYLINDER COMPOUND LOCOMOTIVE,

built by the Brooks Locomotive Works, under patents issued to Mr. John Player, Mechanical Engineer of the Brooks Locomotive Works. The notable features of Mr. Player's patents are shown in the accompanying illustrations.

Referring to Fig. 72, it will be seen that a novel form of receiver has been adopted, and that the combined intercepting and reducing valve is placed in the smoke-box on the right-hand side of the engine. The course of the steam is so clearly indicated in Fig. 72 that further description of the general arrangement of the engine is unnecessary. The intercepting and reducing valve is shown in greater detail and in two positions in Figs. 75 and 76. The position shown in

Fig. 75 is that which the valve occupies when the engine is working as a compound. Suppose that the

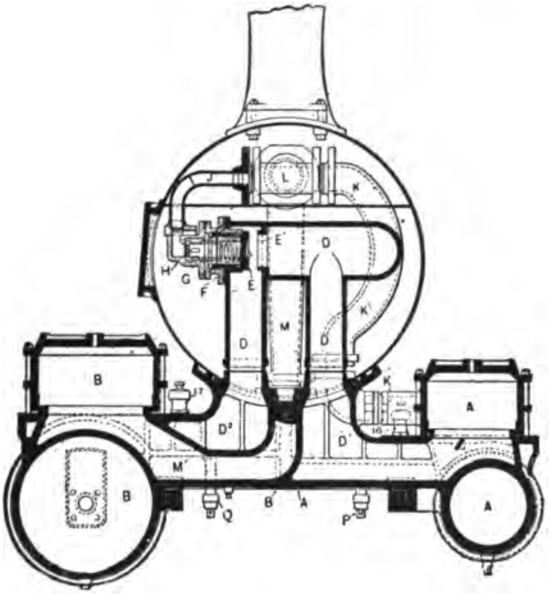


FIG. 72.—THE BROOKS TWO CYLINDER COMPOUND LOCOMOTIVE (Cross-section.)

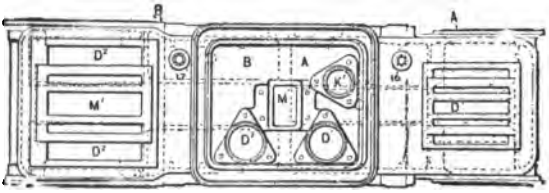


FIG. 73.—THE BROOKS TWO-CYLINDER COMPOUND LOCOMOTIVE. (Plan.)

throttle is opened when the valve is in this position:

live steam enters by the pipe *J*, and pressing on the end of the reducing-valve *G*, opens it, and passes thence through the opening (6) and the cored space in the reducing-valve, and acts upon the back of the inter-

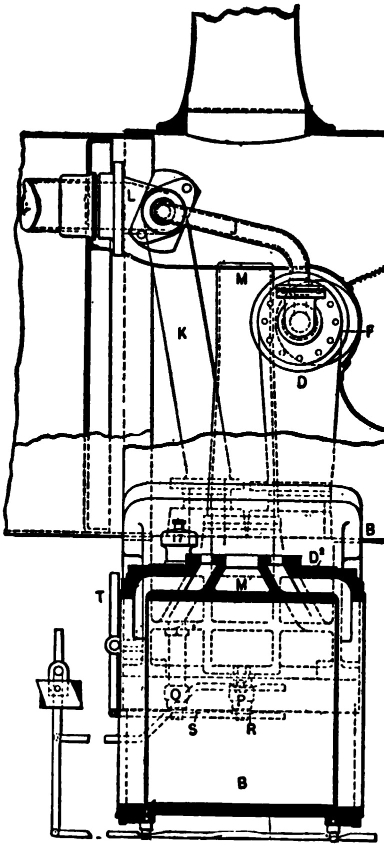
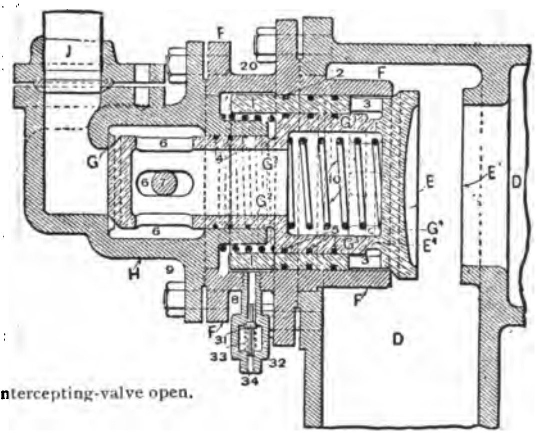


FIG. 74.—THE BROOKS TWO-CYLINDER COMPOUND LOCOMOTIVE.
(Longitudinal Section through Low-pressure Cylinder.)

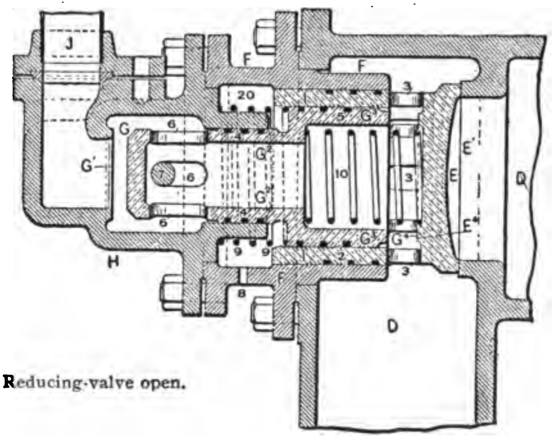
cepting-valve *E*, closing it against its seat *E'*. The valve would then occupy the position shown in Fig. 76. When in this position steam flows through the openings (3) into the low-pressure end of the receiver, and thence to the low-pressure steam-chest and cylinder. The pressure of the steam thus admitted to the low-pressure steam-chest is regulated by the relative areas



Intercepting-valve open.

FIG. 75.—THE BROOKS TWO-CYLINDER COMPOUND LOCOMOTIVE.

of the two ends of the reducing-valve. Under these circumstances steam from the high-pressure cylinder is exhausted into the closed receiver until the back-pressure in the receiver is approximately equal to that of the steam being admitted directly to the low-pressure side. When the pressure on the high-pressure side reaches this point approximately, the intercepting valve *E* is forced open, and by its first movement closes the outlet of the reducing-valve at G_4, thus



Reducing-valve open.

FIG. 76.—THE BROOKS TWO-CYLINDER COMPOUND LOCOMOTIVE INTERCEPTING-VALVE.

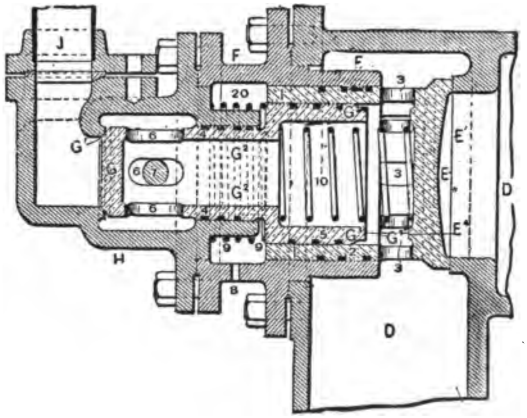


FIG. 77.—THE BROOKS TWO-CYLINDER COMPOUND LOCOMOTIVE INTERCEPTING-VALVE.

closing off the direct supply of steam to the low-pressure side. The difference in area between the large end of the intercepting-valve and the small end of the reducing-valve is then sufficient to enable the receiver-pressure to remove both valves further to the left, as shown in the illustrations, and to close the reducing-valve, thus shutting off the direct supply of boiler steam to the low-pressure cylinder. It will be seen that this valve is, as has been mentioned, a combined reducing and intercepting valve. Mr. Player has patented several other forms of this valve, one of them provided with springs for regulating the action in opening and closing, and also providing for placing the valve in the cylinder saddle. Fig. 77 shows the position of valves with throttle closed and receiver empty.

Another feature of this system of compound locomotives is the arrangement of regulating valves, which is shown by Fig. 74, and at *P* and *Q* in Fig. 72. The object of these valves, which, it will be seen, are operated similarly to the ordinary cylinder-cocks, is, in the first place, to provide an outlet for the exhaust-steam from the high-pressure cylinder when it is desired to move the engine a short distance, as in switching, etc., and, secondly, to provide a means of freeing the receiver and steam, and so taking all pressure off the low-pressure piston, when it is desired to stop the engine within a short distance, as in coupling to trains, etc.

ACCIDENTS TO THE BROOKS COMPOUND ENGINE AND INTERCEPTING-VALVE.

When a main-rod is broken or disconnected on the high-pressure side, how can the engine be run to end of trip?

By running with the low-pressure side.

What should be done in the way of disconnecting in this case?

Cover the ports on the high-pressure side with the valve (and using live steam in the low-pressure cylinder to run with).

How does the steam get into the low-pressure steam-chest?

Through the reducing-valve and intercepting-valve.

Why does not the steam get into the high-pressure steam-chest and receiver?

On account of the live steam in intercepting-valve holding that valve to the seat closing the receiver.

For a broken valve-rod or when disconnected do the same as for a main-rod taken down on that side (disconnecting main-rod).

When a main-rod or valve-rod is broken or disconnected on the low-pressure side, what should be done to run the engine?

The low-pressure valve must be moved back to clear exhaust-port on that side, the piston-head blocked securely in the back end of cylinder.

How can the intercepting-valve be kept open in this case. There must be pressure enough in the receiver to keep the intercepting-valve open.

The way to have a pressure in receiver would be to have the exhaust-port opening very small on the low-pressure side.

Is there any other way of providing an outlet for the exhaust-steam from high-pressure cylinder?

There are regulating-valves tapped in the receiver-passages in cylinder-saddles, but these are not large enough to provide an outlet when pulling cars for any distance; also, the exhaust will be lost on the fire.

How can the intercepting-valve be made inoperative?

By putting a blind-washer in the steam-pipe that joins the reducing-valve chamber. This will prevent any steam from getting into the intercepting-valve to operate it.

When the low-pressure steam-valve is moved all the way back in steam-chest, will it open all the ports?

The valve is liable to drop off its seat in any engine whose seat is higher than the face of receiving-ports, and this will open all ports; but if this should happen, the pressure would be on each side of piston-head. When the intercepting valve is made inoperative, the low-pressure exhaust-port should be opened full.

When from any cause the intercepting-valve is broken so as to leave an opening into the receiver, how could the engine be run as a compound?

Put a blind-washer at joint where the small steam-pipe joins intercepting-valve; this will prevent live steam from getting into receiver.

Do the same for a broken reducing-valve.

When a receiver is broken or badly cracked, what should be done?

The proper way would be to disconnect the high-pressure side and run in with low-pressure side, using steam through the reducing-valve.

Disconnect for other broken parts as for a simple engine.

BROOKS TANDEM COMPOUND LOCOMOTIVE.

The Tandem Compound Locomotive is now in actual use in this country, and the system which is described contains the patents of J. Player, Mechanical Engineer of the Brooks Locomotive Works. The longitudinal section, Fig. 79, shows the cylinder valves and receiver, also piston-heads, ports, and method of packing between the two cylinders. The valves are of two types. The low-pressure valve is a slide-valve having the usual balance-plate, but in this case the plate is made as shown in Fig. 80, this being on account of the rod that is pivoted on top of the low-pressure valve-yoke. The high-pressure valve is a piston-valve, being hollow. The live steam is confined between the two heads of valve, packing-rings are sprung in heads to make it tight. As will be understood, this valve acts directly opposite to that of a common slide-valve in this way, that the lap of the valve is in the inside of heads, or what would be the exhaust side of slide-valve, and exhausts the steam from each end instead of into the centre of valve, as with the slide-valve.

The object of having the valve hollow is to allow the exhaust-steam to pass through valve into receiver. By referring to Fig. 79 it will be seen that the valves are in open communication with each other, the valve-cham-

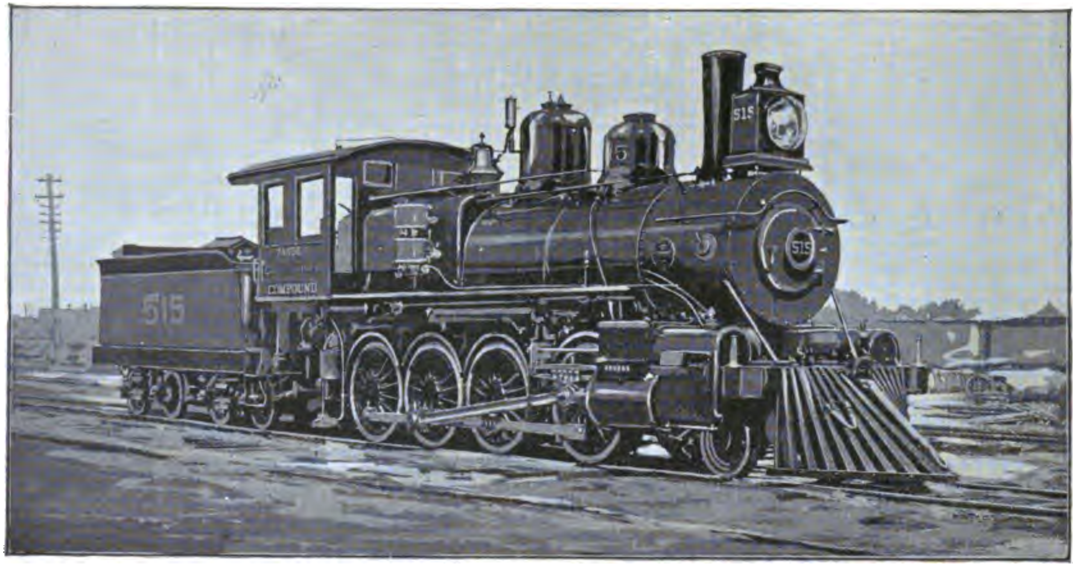


FIG. 78.—BROOKS TANDEM COMPOUND CONSOLIDATION FREIGHT LOCOMOTIVE.

bers acting as a receiver. In the receiver proper is a cross-shaft, on which rotates a rocker-arm ; to the upper arm is connected the rod, which is fastened to the low-pressure valve-yoke. To the lower arm is fastened the rod, which is attached to high-pressure valve. The usual yoke surrounds the low-pressure, valve having its

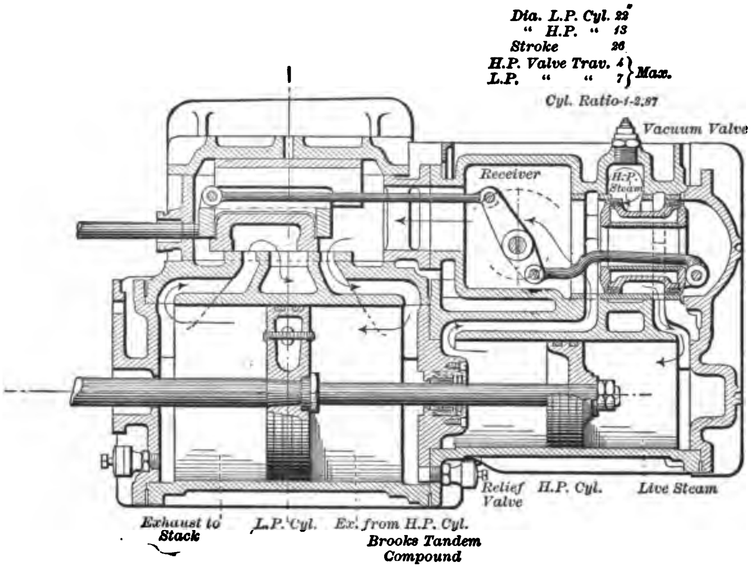


FIG. 79.

stem connected to the valve-rod. The purpose of having the rocker-arm is twofold : First, that by having the arms of different lengths there will be a difference in the travel of the valves, which is a very good point in compounding. When the low-pressure valve travelling 7 inches maximum, the high-pressure valve-travel is 4 inches maximum, so that when using a short cut-off in the high-pressure cylinder you have a wide opening in the low-pressure ports. Second, the valves must travel in opposite directions on account of the high-pressure steam being confined between the heads of high-pressure valve, and by using the rocker-arm * this is accomplished. The action of valves would be as follows: When the low-pressure valve moves to left of Fig. 79 to uncover the front port of the low-pressure cylinder, the high-pressure valve would move to the

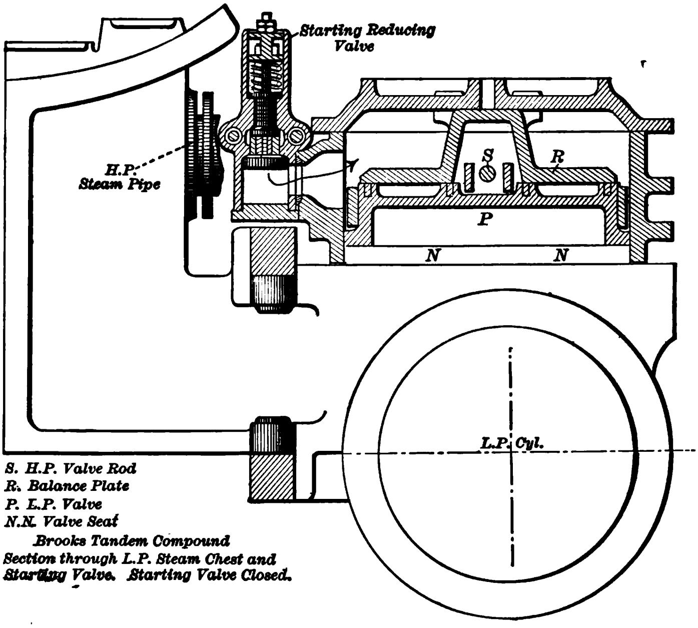


FIG. 80.

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* Builders term, *reversing-arm.*

right and uncover the front of steam-port, and at the same time open back-port of high-pressure cylinder to receiver.

The course of the steam would be as follows: when high-pressure valve opens, the steam enters cylinder, exerting its power against the high-pressure piston-head. The steam that has expanded in the other end of high-pressure cylinder would pass out the back-port into the receiver, from there into the low-pressure steam-chest proper, and into the low-pressure cylinder through the front steam-port, which would be open. The steam in the other end of low-pressure cylinder would pass

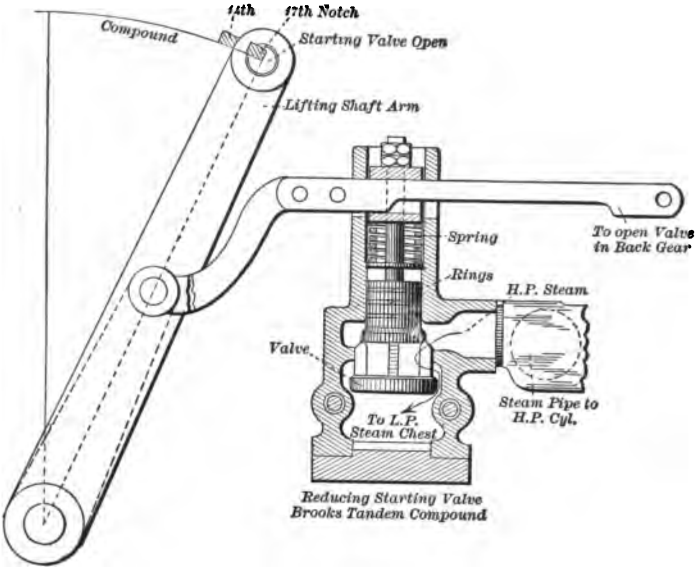

FIG. 81.

out the back-port under the valve into the stack, as with the simple engine.

There is provided a starting-valve on this as on all compounds. This valve is attached to the side of low-pressure steam-chest, and steam-pipe that leads to the high-pressure steam-chest. This valve is simple in construction. Fig. 80 shows the construction and position of valve when closed. Fig. 81 shows the position when open at the time of starting. The valve-casing is bolted to low-pressure steam-chest, and in the lower end of casing is a seat against which the valve, which is a wing-valve, closes. Attached to this valve is a stem which extends up to the top of casing; this valve has two seats, as will be seen: the upper seat is in contact with valve when it is closed; rings are sprung in the extension of valve to keep it from leaking when valve proper is open. To the upper end of the valve-stem is fastened a head having two horizontal openings through it. Between this head and a shoulder in the casing is placed a strong helical spring. The purpose of this spring is to close the valve. Passing through the openings in the head on the stem are two rods of different widths vertically, similar to a cylinder-cock rod. These rods are connected to the reversing-arm of lifting-shaft. The operation is as follows: When the reverse-lever is put all the way down on the quadrant, as when starting a train, the rods are pushed forward in the head on starting-valve stem, the wider part of rod enters the opening, and forces the head and spring down. The live steam then opens the valve and admits steam into the low-pressure steam-chest, at the same time reducing the steam-pressure due to the difference in area of the two sides of the valve proper. When the reverse-lever is put back to the 14th notch, the wide part of rod is withdrawn from the head on valve-stem, the spring will close valve and compounding begins. This action takes place in forward or back gear.

ACCIDENTS TO THE BROOKS TANDEM COMPOUND.

When a main-rod is broken or taken down, what should be done in way of preparing the engine to be run in?

The valves on the side disconnected should be put in the centre of their seats covering all steam-ports, and run with the good side.

When a valve-rod breaks, do the same as for main-rod disconnected.

If a front-head of high pressure cylinder is broken out, what should be done?

The valves on that side put in centre of the seats covering the ports, main-rod taken down, cross-head blocked, and run in with the other side.

Could the engine be run without taking down the main-rod?

By taking off the front head of valve-chamber and disconnecting the high-pressure valve-rod, putting the valve in centre of seat covering the ports, putting a block in the centre of valve so as to carry the rod to clear valve, the reverse-lever put in full forward notch, this will open the starting-valve. Disconnect the rod from the reverse-arm: this will prevent the starting-valve from being closed when the reverse-lever is pulled up. The engine will be running as a compound on one side, and the low-pressure cylinder will act as high-pressure engine on the broken side; this shows what can be done in an extreme case. Care must be taken to keep the high-pressure cylinder oiled; this may be done through the cylinder-cocks or open end of cylinder.

What could be done in case of a broken receiver?

If badly broken, a blind-washer could be put in joint where the steam-pipe joins the high-pressure steam-chest, disconnecting main-rod and blocking cross-head.

If the rocker or high-pressure valve reversing-arm should break off, what should be done?

Put valve in centre of seat covering all ports, take down main-rod, block cross-head, and run in with other side.

How could you cover all ports in this case?

Cover the low-pressure ports by the reverse-lever, then take off the front head of high-pressure valve-chamber, put that valve over ports, and put on head.

How can the high-pressure valve be held in position when disconnected from the rocker-arm?

By cutting a block shape, putting it through the valve, and letting it drop down over the ends of valve, the one end abutting against the rock-shaft in receiver, and the other end held by the head being screwed up against it.

In any break in which the valves can be made to cover the ports, the quickest way is to disconnect on that side and run with good side. As both sides of an engine are constructed alike, these questions apply to both.

In a case where the valves could not be made to cover all ports, a blind-washer put in steam-pipe joint will prevent steam from getting into valves or cylinders.

INTERCEPTING-VALVE FOR COMPOUND ENGINES.*

The intercepting-valve for compound engines here illustrated was designed by F. W. Dean of 53 State Street, Boston, Mass. It is in use on engines on the Old Colony Railroad and on the Lehigh Valley. To the upper side of the casing *A* is firmly bolted the secondary casing *B*, provided with the inner pendent tubular hub *B'*, which extends into the chamber of the lower casing and is bored out to form a cylinder having two different diameters, the upper portion being the larger. The upper end of the cylinder is closed by a cap, connected with which is the pipe *D*, the upper part of which is curved and threaded to receive the end of a pipe leading from the interior of the converting valve D^2, as shown in Fig. 82.

The interior of the casing *A* is formed with a valve-seat for the valve *E*, which is provided with a tubular stem whose outer surface closely fits the smaller bore of the hub *B'*. The bore of the stem is fitted to form a steam-tight bearing on the tube *D*, and it extends through the valve, but of somewhat enlarged diameter, and is threaded to receive a plug the upper end of which is somewhat removed from the lower end of the tube *D* when the valve is raised to its highest position, as shown in Fig. 82. On the upper end of the tubular valve-stem is screwed a sleeve-like piston, formed with two grooves to receive metal packing-rings; the stem is also provided with a pair of packing-rings to work in the lower portion of the cylinder *B'*, and has cut through it just below the packing-rings several rectangular or flat-bottomed radial openings, so located relative to the seating face of the valve and the lower end of the pendent tube *D* that the openings will not begin to be uncovered by passing below the lower end of the tube until the valve has descended nearly to its seat and its outer periphery is partially inclosed by the annular raised rib. Surrounding the valve-seat suitable packing-rings make a steam-tight joint between the tube *D* and the valve-stem.

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* Iron Age.

Live steam direct from the boiler is admitted through the pipe *F*, the upper end of which communicates through the tube-sheet with the steam-space of the boiler, as shown in Fig. 83; but instead of the steam having free access to the chamber through an opening of the size of the pipe, the steam is wire-drawn through a very small hole in a plug or bushing, as shown in Fig. 83.

The tube *D* has drilled through it, just below its junction with the cap, a small hole, through which steam may pass from the interior of the tube to the chamber above the piston, to aid in forcing the valve to its seat.

The casing *B* has formed in its upper part a small vent-hole, the lower end of which opens into a groove in the piston when in its highest position, and its upper end communicates with the annular chamber formed in the upper packing-face of the casing *B*. The cap is also provided with a vent-hole extending from the under side of its flange or its packing-face to the interior of the steam passage through the cap and tube, as shown in Fig. 82, whereby any steam leaking from the

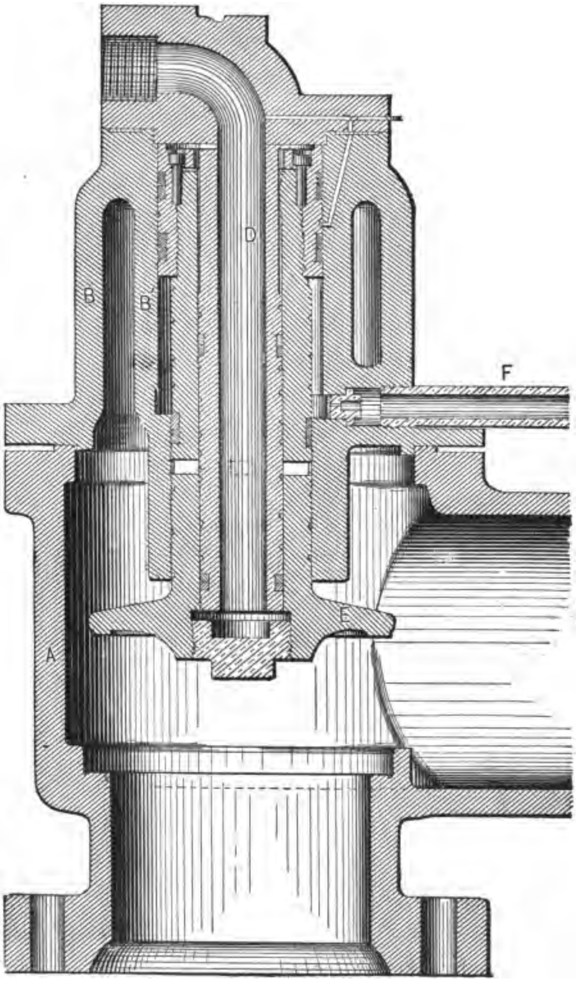


FIG. 82.—F. W. DEAN PATENT INTERCEPTING-VALVE FOR COMPOUND ENGINES. (Central Vertical Section, enlarged.)

chamber and passing the lower packing-rings into the groove can escape into the tube *D*, instead of finding its way past the upper packing-rings into the chamber above the piston.

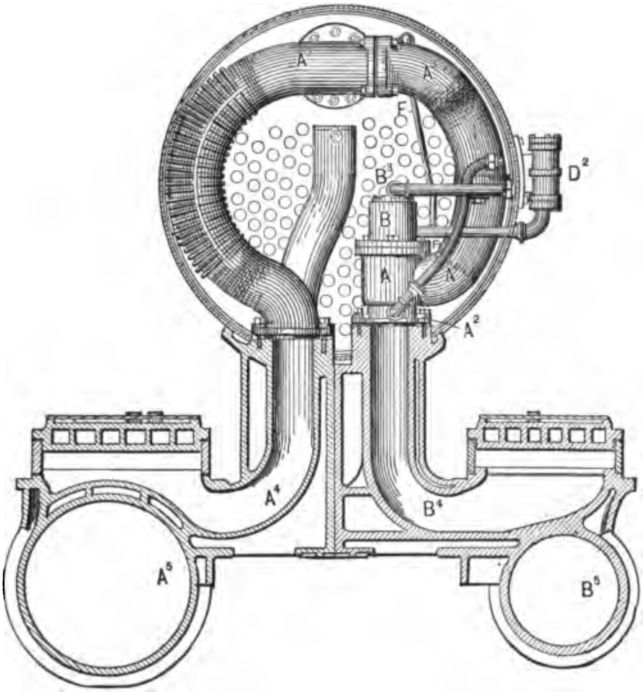


Fig. 83.—F. W. Dean Patent Intercepting-valve for Compound Engines. (Transverse Vertical Section through Smoke-box.)

The area of the annular lower end of the piston in the upper chamber *B'* is approximately equal to the area of the lower end of the pipe *D*, so that the pressure of steam in the chamber will nearly counterbalance the pressure of steam in the pipe tending to move the valve downward, and so maintain the valve in its elevated position until steam enough has passed through the small opening in the upper part of the pipe *D* into the chamber above the piston to overcome the upward pressure in the chamber. The valve then moves downward as fast as the steam can pass through the opening until it has nearly reached its seat, when the openings in the valve-stem will permit the escape of steam from the pipe *D* into the chamber *A*, and the valve will seat without jar.

By admitting the live steam from the boiler to the chamber through the small orifice in the bushing of the pipe *F*, the upward movement of the valve *E*, which is started promptly by the steam in the chamber, which is substantially at boiler-pressure in its continued upward movement, will be somewhat retarded by the restricted supply of steam which can pass through the orifice, and as some steam will remain in the chamber above the piston, which can escape only as fast as it is forced through the orifice into the pipe *D*, the upward movement of the valve will be arrested without slam or jar.

The construction shown and described insures the opening of the valve *E* before the pressure of exhaust-steam in the high-pressure exhaust passage accummlates above the receiver-pressure, and thus relieves the high-pressure piston of the early back-pressure, as the valve being acted upon by the steam in the chamber at substantially boiler-pressure is made to open promptly, when the converting valve is closed and a passage is opened from the interior of the tube *D* to the atmosphere, and is also opened in advance of an accumulated back-pressure on the high-pressure piston.

The cap is connected by a pipe with the converting-valve, and as a consequence it follows that when the converting-valve is closed the steam in the tube *D* is free to escape into the open air, and as the converting-valve is closed as soon as the high-pressure cylinder begins to exhaust, it follows that before the pressure of the exhaust can accumulate above receiver-pressure the pressure above the valve *E* will have been relieved and the pressure in the chamber will have commenced to raise the valve *E* to open communication to the receiver.

CHAPTER XII.

INJECTORS, SAFETY-VALVES, STEAM-GAUGES, ETC.

THE INJECTOR.

THE injector is a part of the locomotive machine that must always be in perfect condition. Any defect in it will prevent it from working, and place an engineer in a very bad position, as on it he must depend to get water into the boiler, for the day of pump-using is past.

There are usually two injectors on a locomotive, so that if one fails the other may be used. The action of the injector seems a mystery to many, in regard to the manner in which the water is forced into the boiler, at or above the steam-pressure which is working it.

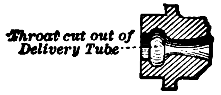
The operation is as follows:

Steam under pressure acquires a very high velocity in escaping through a tube. Then the steam passing from the boiler in the steam-nozzle *N*, and having a high velocity, comes in contact with the water in combing-tube *O*, condenses, and also imparts to the water its own velocity. Water being a heavier body and acquiring the velocity of the steam, passes from the combining-tube into the delivery, from there it strikes the check with sufficient force to raise it against the boiler-pressure.

If the steam is not perfectly condensed, the injector will not work, but will spray and cause it to fly off, in most automatic-regulating injectors. In answer to the question, "Why does it force water against a higher pressure than that which is working it?" we answer: A pressure in motion is working against a pressure at rest, or without motion. The pressure in motion is the steam escaping from steam-nozzle combining with the water imparting to it its velocity. The pressure at rest or without motion is the steam in the boiler into which the water is being forced. The pressure in motion having the greater power (due to the velocity and weight acquired), overcomes the pressure without motion.

The most simple form of the injector is shown in Fig. 84. *N* is a steam-nozzle, which extends into the tube *O*, which is called the combining-tube. In this tube the steam and water combine, the mouth of the combining-tube being open to the water-chamber *R*. In front of the combining-tube is the delivery-tube *E*. Beyond this is the overflow and end check.

FIG. 86.



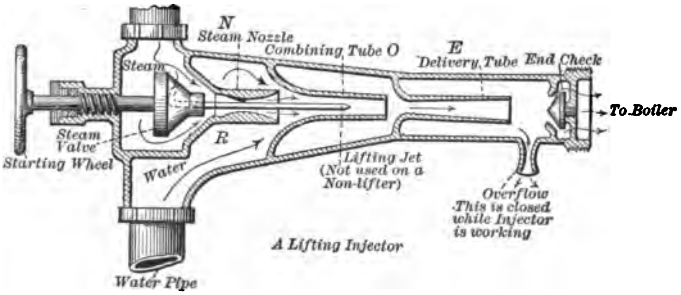
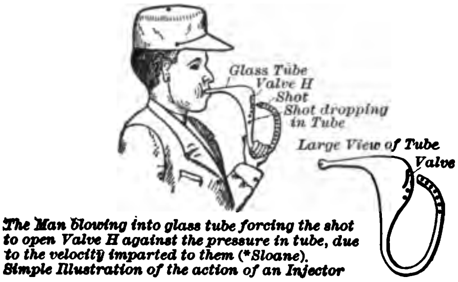


FIG. 84.

The capacity of an injector is known by the diameter of the smallest tube, which is the delivery-tube. The purpose of the overflow is to allow the steam, which is creating a vacuum, to escape. Also, for the water to acquire a velocity before being forced into the boiler.

A very simple illustration of how an injector operates is shown in Fig. 85. The man is blowing into the tube, which has a valve at *H*, which opens inward. The neck of the tube is bent around and the end is in line with the valve *H*, and the diameter about the size of shot. The tube has some shot in it, and when the man blows into the tube the shot will acquire a velocity, issue from the tube, and strike the valve *H* and open it against the pressure that gives to it its velocity.*



*The Man blowing into glass tube forcing the shot to open Valve H against the pressure in tube, due to the velocity imparted to them (*Sloane). Simple Illustration of the action of an Injector*

FIG. 85.

When an injector fails to work, the tank-valve should be examined, and if that is found to be open, the next point is to take down the screen and see if there is any dirt in it. Blow the injector out with a little steam. After this, if it does not work correctly, examine the joints in water or suction pipe and see if any air enters: if there is, tighten them up; and if all these necessary matters have been attended to, the injector will now probably work correctly.

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* Professor Sloane.

Do not start out on the road until you are assured that both injectors are working correctly, for the right-hand one may fail at any time.

When an injector gets hot, the best way to make it work is to let the hot water out at the screen. Sometimes they can be made to work by blowing the water back into the tank, first dropping the tank-valve. When this is done, open tank-valve quickly and start suction. Another way is to pour cold water over the injector and pipes.

At present the lifting and non-lifting injectors are in use, also the restarting.

A lifting-injector is one that will lift the water to combining-tube. The non-lifting will not lift the water, but the water must flow to it. The restarting injector is one that, should the water-supply be stopped and then return, the injector would start to work again, as there is a continuous suction.

The difference between a lifting and restarting injector is, that in a lifting-injector there is generally a closed overflow, and when from any cause the flow of water or steam is stopped, the injector breaks and cannot go to work, because, there being no outlet for the steam except back into the tank through water-pipes, this forces the water away from the injector and makes it hot.

In a restarting injector (which is a lifting-injector also) there is a free overflow, which is opened by the steam, and the tubes are provided with suitable openings. When the water breaks, the steam, instead of passing back into the water chamber and pipe, escapes beyond the combining-tube into the atmosphere, forming a continuous suction in the water-chambers, and when water returns it will go to work again; but if the overflow is fastened shut, it will not restart, but be as a closed overflow. A closed overflow seems to be preferred, as it will not let the water overflow into the waste-pipe when there is much variation in the pressure.

In fitting up an injector, all the tubes should be in line and free from obstruction inside; the joints on water-pipe must be tight, or the injector will not lift on account of the vacuum being impaired.

Another cause of the failure of an injector to work is dirt in the tube—usually the delivery-tube. This will generally be known by the steam being driven back in the tank, also by dirt, such as fine coal or waste, in the tank valve or screen. These obstruct the flow of water and prevent the injector from working. The screen should be taken down before going out on each trip.

Another cause of the failure of the injector to work is when the delivery-tube becomes worn or cut out at the throat. (See Fig. 86). This is caused by the tube being struck by the water after leaving the combining-tube, due to the velocity with which the water strikes it. This tube is the one that wears out most quickly.

Many trials have been made to get an injector to force very hot water, but the failure to do so in the past has been caused by the temperature of the water being too high to condense the steam, which it must do before it will work. It is known that hotter water can be forced with steam of a low pressure than with that of a high temperature, for the reason that steam of a low temperature has less degrees of heat to be absorbed by the water, and can be condensed by water of a higher temperature.

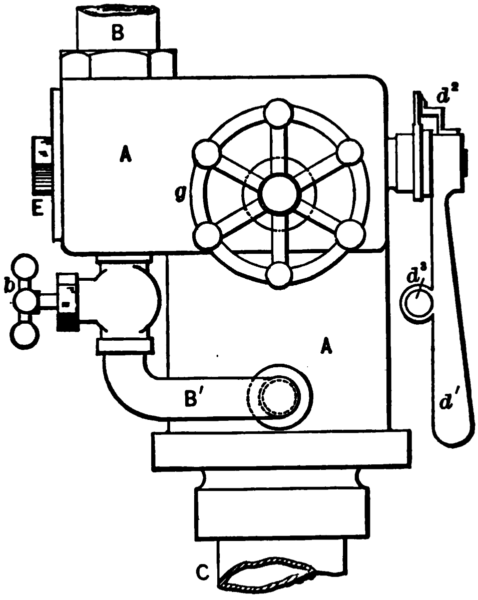


FIG. 87.—THE REAGAN INJECTOR. (Rear Elevation.)

The author has taken advantage of this point in injector of Fig. 87, where he converts the steam of a high temperature to a low temperature, before it combines with the water in the combining-tube.

The object sought for in the Reagan Injector was the construction of an injector that would force water

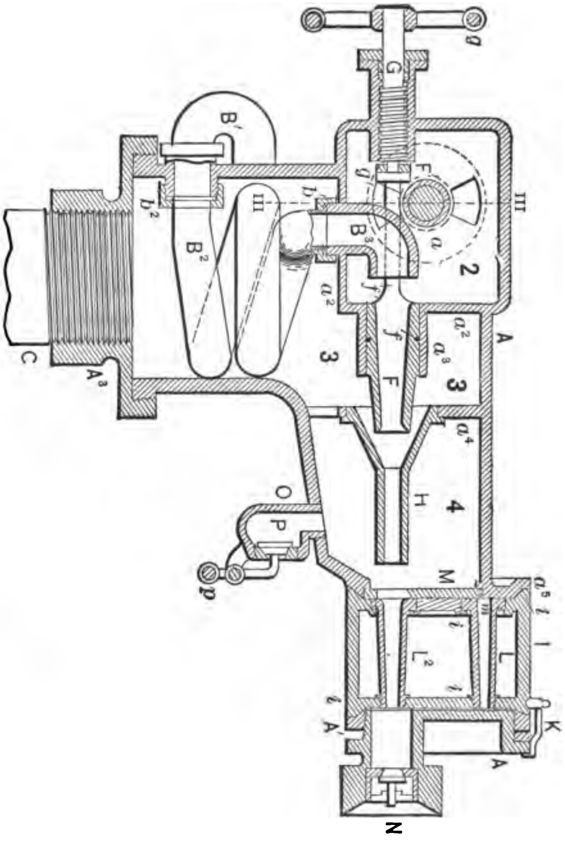


FIG. 88.—REAGAN INJECTOR. (Longitudinal Vertical Section.)

of a high temperature, to be a multi-tube injector, and to reduce the complication of the construction as much as possible.

The first point, that of forcing hot water, is accomplished by cooling the steam before it reaches the combining-tube, as in Fig. 84. The steam passes through the coil of pipe in water-chamber. This has the effect of reducing the temperature of the steam, so that it will readily combine or be condensed by the water of a high temperature.

This pipe can be passed through any body of water

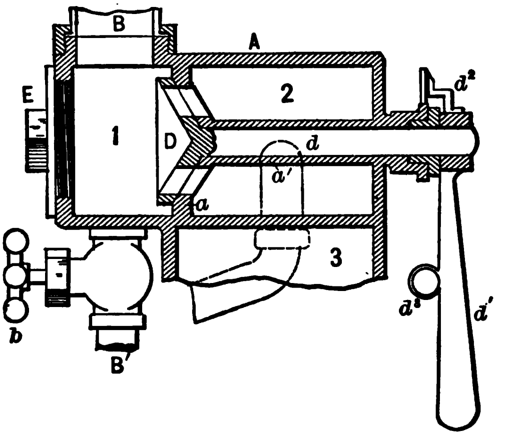


FIG. 89.—THE REAGAN INJECTOR. (Vertical Cross-section on Line III III of Fig. 88.)

away from the injector, so that it is brought back to the steam-chamber again.

The second feature, that of multi-tubes, is accomplished by having a rotating cylinder, into which tubes are fitted as in Fig. 88. There can be combining and delivery tubes in line, thus making a multi-capacity injector, by rotating the cylinder in front of the steam-nozzle.

Another feature is that of making the steam-nozzle act as a water-regulating valve, thus doing away with an extra valve.

Also, the steam-valve is fitted without packing, which is a valuable feature in an injector.

QUESTIONS.

Name the different parts of an injector as shown in Fig. 82.

They are the steam-valve and tube, the combining-valve and delivery-tube, the overflow and the check.

What takes place in the combining-tube?

The steam combines with the water and imparts to it a higher velocity.

By what tube is the capacity of an injector rated?

By the smallest diameter of the delivery-tube, and by the pressure.

Which tube receives the most wear, and why?

The delivery-tube receives the most wear, because it receives the water from the combining-tube, which has a high velocity, striking the delivery where the diameter is smallest.

What is the effect on the injector? (See Fig. 84).

Its cuts out the throat of the delivery, which prevents it from working when much worn.

For what is the overflow used?

It is used to allow the water to acquire a high velocity before closing it out and forcing the water in boiler; also, to have an outlet for the steam, which forms the suction to lift the water to the combining-tube.

What causes an injector to fail to work?

There are several causes: small supply of water caused by dirt in screen, dirt in tubes, tubes out of line, loose pipe-joints which impair the vacuum, and injector getting hot.

When an injector fails, what should be done?

Would look for any or all the causes stated.

When an injector gets hot, what is the best way of getting it to work?

By letting the hot water out at the screen, or by cooling the injector with cold water.

What is the difference between a lifting and a non-lifting injector?

In a lifting-injector the water is raised by the steam forming a vacuum; in a non-lifting, the water must flow to it.

What is a restarting injector?

An injector which will recommence work without the attention of the engineer, when from any cause the steam or water should have been stopped.

Why does it operate in this way?

The overflow is free or open, and the steam can escape into the atmosphere, forming a continuous vacuum.

Why is it that an injector with a closed overflow cannot restart?

Because the steam can only escape back into the water-pipe, which forces the water into the tank.

How can a restarting injector be changed to a non-restarter?

By closing the overflow-valve tight; this would make a heater out of it.

When running an engine, and it should become snowbound, what should be done to prevent freezing of injectors and pipes?

The frost-cocks should be opened and the water drained out of pipes and injector.

Are non-lifting injectors much used on locomotives, and are there any points in favor of the non-lifter?

There are not many used, but they have the advantage that the tubes do not become coated with sediment as does a lifting-injector, because the water surrounds the tubes and keeps them cool; in a lifting-injector the water falls away and the tubes become dry.

Is it policy to start out on the road without examining both injectors, or if the right-hand one should fail just before starting?

No, it is best to know that both are in working condition.

What should be done in cold weather with the left injector?

A heater should be made out of it to prevent it from freezing up.

Why does the right-hand injector not freeze also?

Because it is being used, and water in the pipes being kept in motion prevents it from freezing.

The injectors that are shown are of three types—single tube, non-restarting; double tube; and a restarting. All are lifting-injectors.

WILLIAM SELLERS & CO., INCORPORATED.

The cuts (Figs. 90, 91) show the new restarting injector of 1887. As will be seen, the principal difference between this injector and others is, that if from any cause the flow of water or steam is interrupted and then returns, the injector starts to work without attention, as long as the overflow-valve is open. To make a heater the overflow-valve is closed.

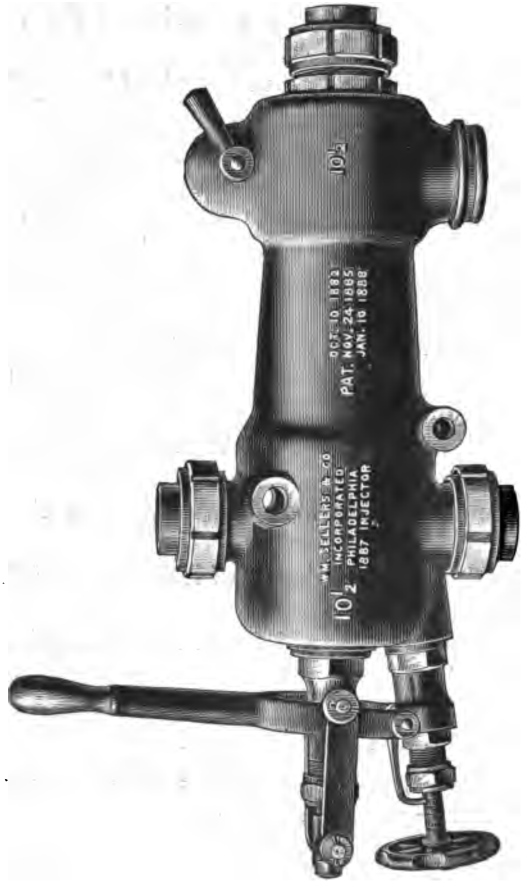


FIG. 90.—WILLIAM SELLERS & CO.'S RESTARTING INJECTOR. (Perspective View.)

Its construction is such that small particles of dirt, etc., are not liable to interfere with its working; and as its tubes are in a straight line, a wire can readily be passed through them to dislodge an obstruction if necessary. By simply disconnecting the pipe union at

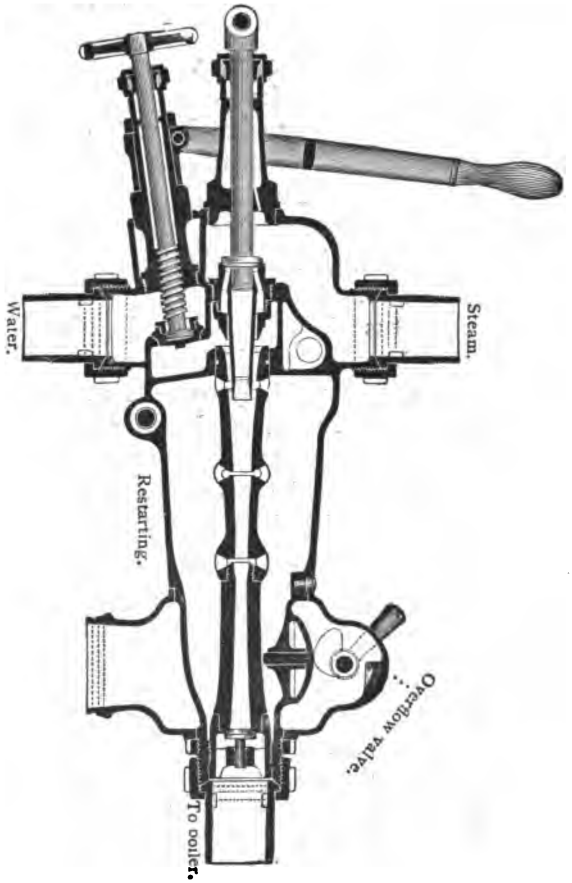


FIG. 91.—WILLIAM SELLERS & CO.'S RESTARTING INJECTOR.
(Sectional View.)

the delivery end of the injector the combining and delivery tubes may be taken entirely out.

Its manipulation when lifting the water is extremely simple:

To start.—Pull out the lever.

To stop.—Push in the lever.

Regulate for quantity with the water-valve.

When the water flows to the injector it is of course necessary to open the water-valve before pulling out the lever, and to close it after pushing in the lever.

In starting on high lifts and in lifting hot water it is best to pull out the lever slowly.

This apparatus will be found applicable to all kinds of service, and perfectly reliable under conditions much more severe than any likely to arise in ordinary practice on locomotives or on stationary or marine boilers. It will start at the lowest steam-pressures with water flowing to it, and will lift the water promptly, even when the suction-pipe is hot. At 10 pounds steam-pressure it will lift the water two feet; at 30 pounds,

CAPACITY OF INJECTOR.

Size No.	Cubic Feet per Hour at 120 lbs.	Gallons per Hour at 120 lbs.	Size of Pipe-steam and Delivery.			
			Iron.	Copper.	Water-Supply	
					Iron.	Copper.
4 3/10	75	562	¾	1	¾	1
5 4/10	118	885	1	1⅛	1½	1⅛
6½	170	1275	1¼	1½	1½	1¾
7½	227	1702	1¼	1½	1½	1¾
8½	291	2182	1¼	1½	1½	1¾
9½	364	2730	2	2	2	2¼
10½	444	3330	2	2	2	2¼
11½	530	3975	2	2¼	2	2¼

five feet; and at all ordinary pressures, say 60 pounds and over, it will lift from twelve to eighteen feet.

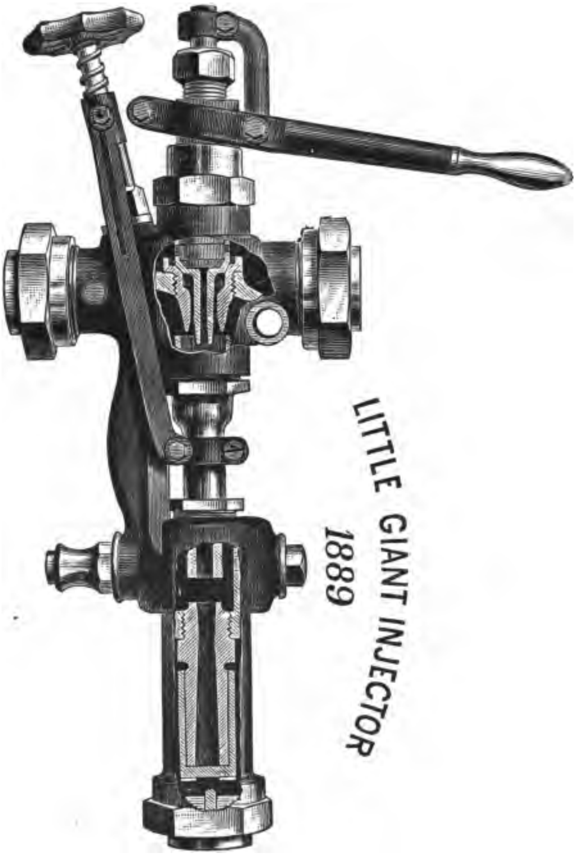


FIG. 92.

It requires no regulation to work without waste of water for any variation of steam-pressure above 40 pounds.

RUE INJECTORS.

The combining-tube is adjusted by a screw which gives very fine graduations. This pattern of injector (manufactured by the Rue Manufacturing Co.) conforms to the latest standard, and can be used in place of such with little if any change in pipes.

Directions for Operating.—To start injector: Have the combining-tube in position to allow sufficient water to condense the steam when starting-valve is wide open. Then open the starting-valve slightly; when water shows at overflow, open starting-valve wide, where it should remain while injector is at work. The quantity of water is graduated by moving the combining-tube. Towards the discharge gives *more* and towards the steam gives *less* water.

To stop injector: Close starting-valve. To use as a heater, close overflow by moving combining-tube against the discharge, and open steam-valve to admit what steam is required.

Size of Injector.	Copper Pipe, Outside.		Iron Pipe, Inside.		Gallons of Water per Hour with 125 Pounds Steam.
	Steam.	Water and Delivery.	Steam.	Water and Delivery.	
4	1¼	1¼	1	1	600
5	1½	1½	1¼	1¼	950
6	1½	1½	1¼	1¼	1275
7	1¾	1¾	1½	1½	1800
8	1¾	1¾	1½	1½	2250
9	1¾	2¼	1½	2	2800
10	1¾	2¼	1½	2	3500

THE METROPOLITAN DOUBLE-TUBE INJECTOR.

The locomotive injector shown in the engravings, in perspective and in section, is an improved form by the Hayden & Derby Manufacturing Co. of New York. The construction of the apparatus is simple.

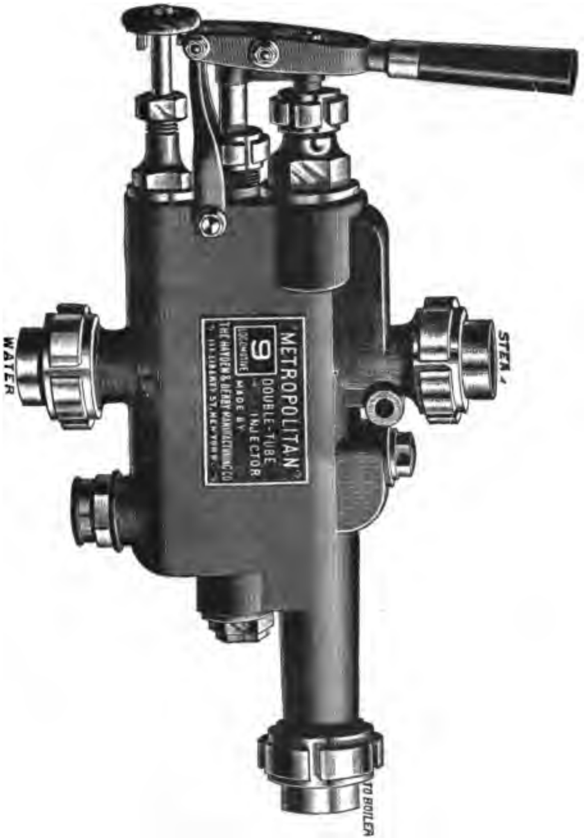


FIG. 93.—METROPOLITAN DOUBLE-TUBE LOCOMOTIVE INJECTOR.

There are no outside attachments to become broken or interfere with placing the numerous attachments necessary in a cab. The tubes are all removed from the back end of the injector, and can be taken out without taking the injector off the engine. The valve-seats are independent of the body casting, and can be easily replaced or reground. This latter feature is a particularly good one, as there is no necessity to put the body casting in a lathe to turn up the valve-seats. The overflow-valve stem is attached rigidly to the steam-valve stem, and when the injector is working the overflow is closed and the valve held to its seat by boiler-pressure.

Water cannot then run out of the overflow, and it is not necessary for an engineman to look out of a cab to see whether the injector is feeding or the water escaping from the overflow.

The sectional view shows all of the parts so clearly, that description is not necessary. At 6 is shown the steam-valve, and the parts relating to it are numbered 1 to 5. The forcing steam-tube is shown at 7, and the combining-tube at 8. At 10 is shown the line check-valve. The overflow-valve stem is shown at 12, and the valve and its seat and other parts at 16, 17, and 47. The regulating-valve wheel is shown at 20; 24 and 25 show the lifting steam-tube and combining-tube.

Another important feature claimed for this injector is that the capacity steadily increases as the steam pressure increases. For instance, with 125 lbs. steam-pressure the No. 9 injector has a capacity of 2900 gallons of water per hour; with 150 lbs. steam-pressure this capacity is about 3000 gallons of water per hour;

and with 180 lbs. of steam-pressure it is about 3075 gallons of water per hour. These injectors will start with 25 lbs. steam-pressure, and without any regulation

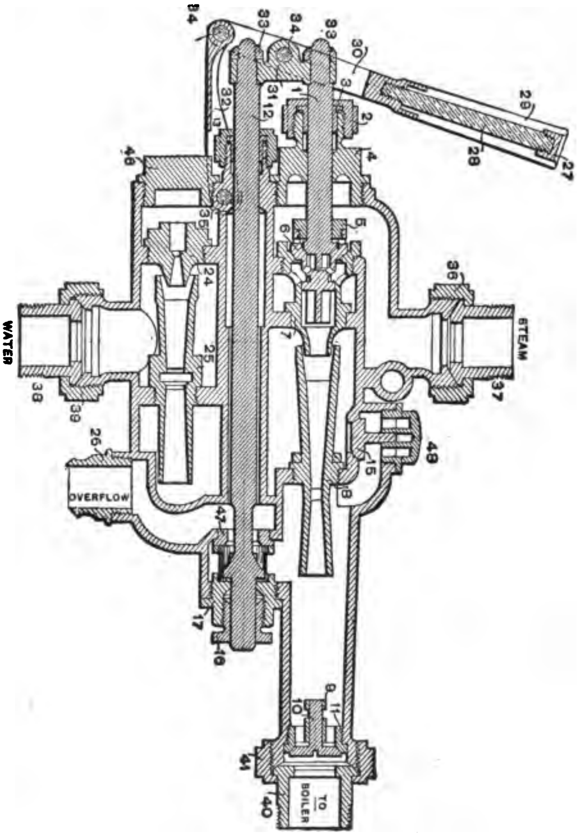


FIG. 94.

the steam or water supply will work at all steam-pressures up to 250 lbs. It is found that the independent lifting and forcing apparatus permits easy and close regulation of the capacity, and owing to this apparatus these injectors are strong lifters, and no matter how hot the injector or suction-pipe may become, the injector will promptly lift the water. In the most severe test it has been found that it never requires over 30 to 40 seconds to bring the water, even after the injector has been used as a heater for some time.

SAFETY-VALVES.

The safety-valve is a very important device on any steam-boiler, as it governs the amount of pressure that can be carried by the boiler, forms the outlet for any pressure in excess of that which should be carried, and prevents boiler explosions due to high-pressure. This valve should not be tampered with after being set, especially by one not understanding its construction. Locomotives, as a rule, have two safety-valves on them: one is a lock-pop safety, and the other is not locked. The lock-pop is generally set at about 5 lbs. higher than the other, thus making it a positive safety, for if the other were tampered with, the lock-pop would relieve the boiler. A safety-valve must be able to rise at the predetermined pressure and relieve the boiler, and then close, thus preventing any further escape of steam until it reaches the proper pressure. There was this trouble in safety-valves prior to the Richardson safety, that when the valve raised it increased the tension of the spring, and caused the valve to close before the boiler was relieved of the proper amount of pressure, and then if the area of the valve were increased with a spring of the same tension, the valve would stay open too long and reduce the pressure 15 or 20 lbs.,—not only an uneconomical but a very bad feature on a locomotive hauling heavy trains or on heavy grades. The first successful safety-valve was brought out by a locomotive-engineer named Geo. Richardson, who ran on the Troy and Boston Railroad. The construction is shown in Fig. 95. As will be seen, the valve on the outer edge has an adjustable lip *C′C′*, which can be raised or lowered, and is locked in position by the set-screws *LL*, which fit in the indents *K*; this prevents the lip from turning around. The body of valve behind the lip is hollow, as *CC*; the seat has a cavity around it, as *aa*, into which lip *C′C′* projects. The action of this valve, then, is to get an increased pressure to hold the valve up without increasing the area of the valve proper, which is accomplished in this manner: When the valve rises the steam fills in the cavity *CC*, and is then diverted by the lip *C′C′* down into the cavity *aa*, this produces a reaction or gain of pressure against the valve, and helps to hold it up. To increase the time that the valve will stay up and the amount of pressure reduced, the adjustable lip should be screwed down, which will reduce the opening between the lip *C′C′* and the cavity *aa*. To cause the valve to close quickly and not reduce the pressure too much, the lip should be raised. The proper position at which the valve-lip should be set is when the valve will close at a pressure of 3 to 5 lbs. less than that at which it raised. Bear in mind that it takes but a very little movement of the lip to make a great difference in the action of the valve. To increase the tension of the spring *m*, Fig. 97, the nut *R* is screwed down. The valve in Fig. 97 is a

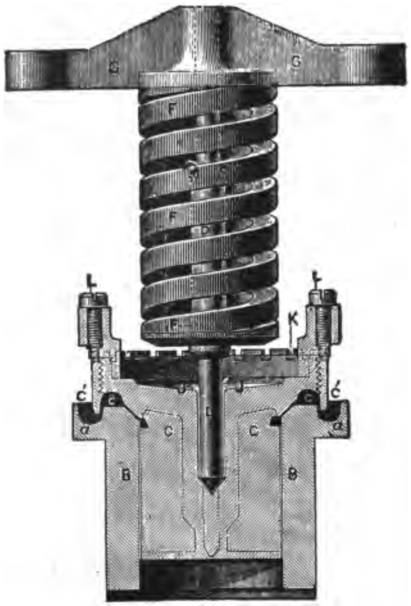


FIG. 95.

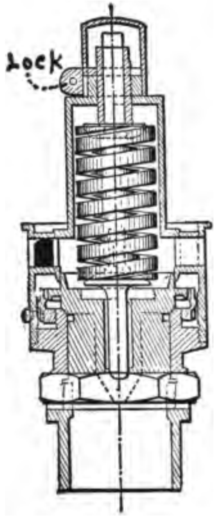


FIG. 96.

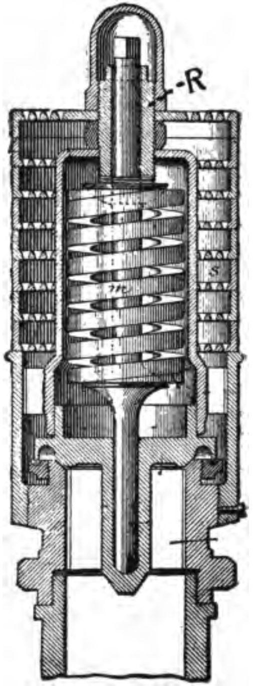
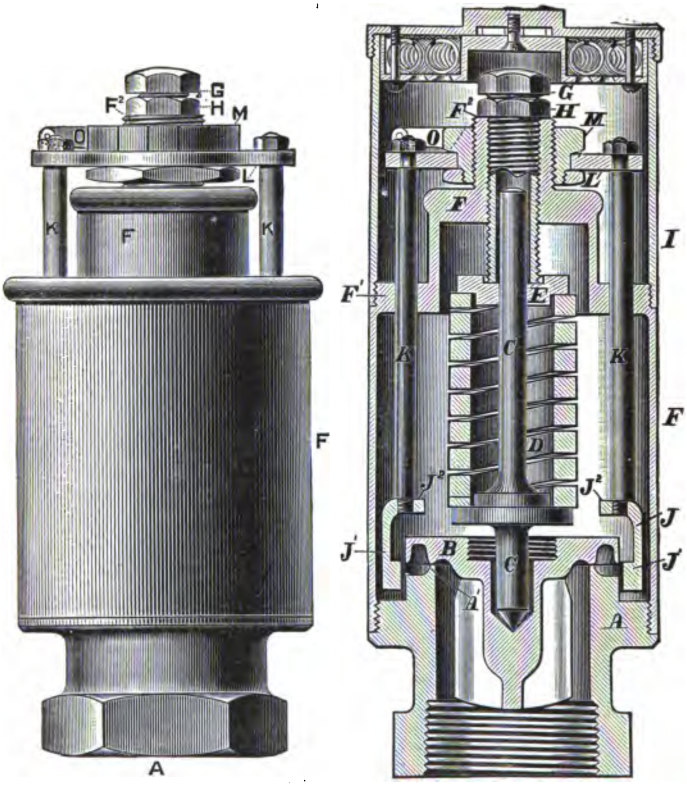


FIG. 97.

combined safety-valve and muffler; the steam passes through the plates in the casing, which are full of holes;



OUTSIDE VIEW WITHOUT MUFFLER. INSIDE VIEW WITH MUFFLER.

FIG. 98.—THE KINNEY LOCOMOTIVE SAFETY-VALVE.

A, base; *A'*, valve-seat; *B*, valve; *C*, spindle; *D*, spring; *F*, follower; *FF'*, main casting; *F²*, thread-hub; *G*, compression-screw; *H*, check-nut; *I*, muffler; *J*, regulating ring; *JJ'*, lugs of ring; *K*, parallel rods; *L*, cross-head; *M*, adjusting nut; *O*, locking-latch.

this has a tendency to break the force of the steam before it reaches the atmosphere, thus reducing the noise, which was a great nuisance to the public in the older form of valves.

Another design of safety-valve which is coming into use is that of Fig. 98. The claims are in the adjustment of the valve. In order to adjust either the pressure or the blow-down, first remove the muffler *I*; this exposes the compression-screw *G*, adjustable nut *M*, cross-head *L*, locking-latch *O*, and check-nut *H*. Screwing down the compression-nut *G*, the pressure is increased, and the reverse for lessening the pressure. As a rule, from $\frac{1}{16}$ to $\frac{1}{4}$ turn will change the pressure of the valve 5 lbs. either way. By raising the locking-latch *O* screw down on the adjusting-nut *M*, the blow-down is reduced 1 lb., and the reverse increases it 1 lb. This valve can be adjusted without being taken off the dome, made by American Steam Gauge Co., Boston, Mass.

STEAM-GAUGES.

Two forms of steam-gauges are in general use on locomotives, one using a diaphragm, and the other using a hollow tube in the shape of a letter C, having an elliptical section. In the gauge having a diaphragm the pressure is behind the diaphragm, which is fastened on a round chamber, the diaphragm acting as a head, which is steam-tight. The face of diaphragm is corrugated. The pressure bearing against the diaphragm causes it to bulge out in the middle, and the amount that the middle rises depends on the pressure behind it. Bearing against the diaphragm in the centre is a bell-crank lever; attached to the other arm of lever is a link, which is connected to a segment having teeth; this segment is pivoted on the lower end. In contact with teeth is a small toothed pinion; to the shaft of this pinion is attached the hand or pointer. Any movement of diaphragm will move the hand through the mechanism just described.

In the other form, Fig. 99, the pressure acts on the inside of tube *cc*; this pressure causes the end of tubes to straighten out, thus spreading the ends, to which is attached the bent lever *CFLM*. This is connected to the toothed segment *e* by rod *R*; the segment *e* rotates the small pinion and shaft *S*, which carries the index or hand *PP* of gauge. By having the lever *CFLM* attached to the ends of tubes *a*, *c*, as in Fig. 99, the distance the lower end of lever *CFLM* moves is double that

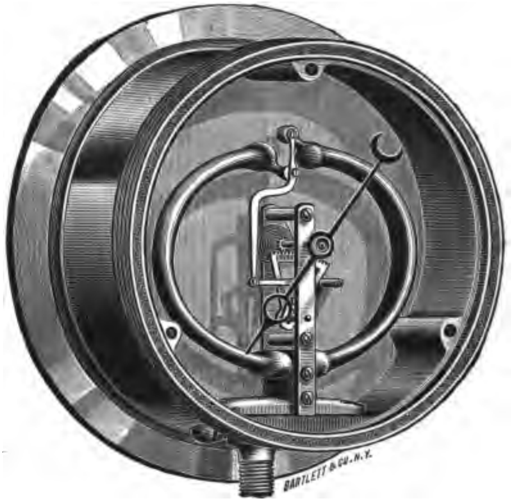


FIG. 99.—IMPROVED STEAM-GAUGE.

which it would be if only attached to one end of tube, and having the fulcrum rigidly connected. The tubes are made of brass, and are seamless,—which is a great improvement, and required some time and money to accomplish it. The great trouble with the brazed tubes was, that they would leak, this would destroy the accuracy, and steam escaping inside the gauge would make it hard to see the dial. The tubes are attached to boiler by a pipe attached at *H*. The seamless-tube gauges are made by the Ashcroft Manufacturing Company of New York. On all gauges the pipe connecting gauge with boiler is bent in the shape of the letter S. The idea of this is to prevent the steam from coming in contact with the diaphragm or tubes, as this would affect their elasticity. The steam is condensed in the

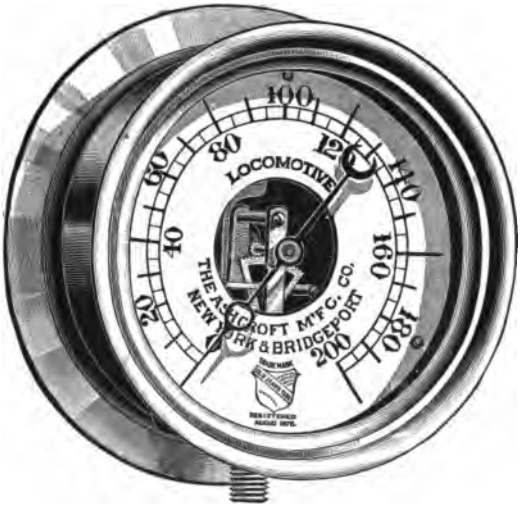
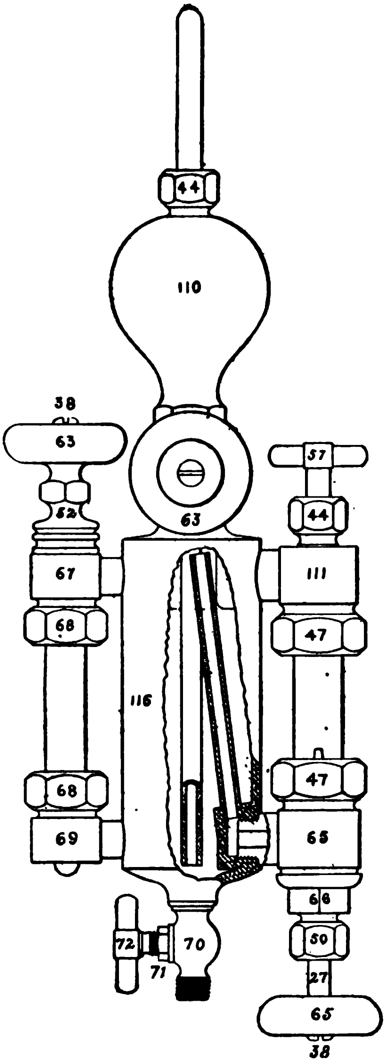


FIG. 100.—IMPROVED STEAM-GAUGE.

pipe, and the steam-pressure forces the water up into tubes or diaphragm-chamber; this pipe is provided with a cock to close when it is desired to remove the gauge when steam is in boiler. Gauges get out of order, or do not register correctly, and then are called heavy or light gauge.

A heavy indicating-gauge is one that registers more than there is pressure in boiler.* A light indicating-gauge, one that registers less than pressure in boiler. A heavy indicating-gauge is very often caused by the diaphragm becoming set or extended; some tube-gauges will do the same. In this case the hand will not come back to the pin, but will show 10 or 15 lbs. without any pressure in the boiler. A light indicating-gauge may be caused by the tubes or diaphragm not moving the proper distance at which the dial was marked off at the time it was tested when made, or by a dial moving around. Another cause is any lost motion in the mechanism which would cause a light indicating-gauge, for the tubes might be moving the proper distance, but the mechanism would not move the index the proper distance on dial. In a diaphragm-gauge any dirt that would get between the end of bell-crank lever and diaphragm would cause a heavy indicating-gauge. Another cause is the opening to diaphragm or tube becoming corroded or clogged up, not allowing the pressure to act as it should in tubes or diaphragm.

*** The terms *light* and *heavy gauge* are used in a different manner when testing a gauge. A gauge is said to be *heavy* when it indicates less than test gauge, and a *light gauge* when it indicates more than test gauge. In the first case it would require 90 lbs. of steam in boiler to make it indicate 80 lbs. of steam. Second case it would require 70 lbs. to make it indicate 80 lbs. of steam.**



27. Feed-valve Stem.
38. Handle-button.
43. Globe-valve Centre-piece.
44. Globe-valve-stem Nut.
44. Equalizing-tube Nut.
44. Pulsating-stem Nut.
45. Globe-valve Stem.
47. ¾ Nut.
50. Feed-stem Nut.
52. Filler-plug.
57. Pulsating-valve Stem.
62. Globe-valve.
63. Wood-handle.
65. Lower Feed-arm.
66. Feed-valve.
67. Upper Gauge-arm.
68. ⅜ Nut.
69. Lower Gauge-arm.
70. Drain-valve.
71. Drain-valve Centre-piece.
72. Drain-valve Stem.
110. Condenser.
111. Upper Feed-arm.
112. Support-arm.
113. Right and Left Coupling-nut.
114. Support-post.
115. Equalizing-tube.
116. Body.

FRONT. VIEW.

FIG. 101.—THE "DETROIT" NO. 1 IMPROVED AIR-PUMP LUBRICATOR. (New Style.)

LOCOMOTIVE-CYLINDER LUBRICATORS (DETROIT).

In this lubricator, as in all others of this class, the weight of a volume of water displaces the oil in the oil-reservoir, causing it to flow upward through water in glass tubes, which open into the pipe leading to the steam-chest. The method of filling and the operation of the lubricator is as follows: Before filling the reservoir the valves must be closed to prevent any steam from getting into the lubricator.* The valves first to be closed are the water-valve 9 and the feed-valves 26; then open the drain-valve 33, and let the water of condensation run out, removing the filler stopple 42. After filling the reservoir the stopple 42 should be put in, and the steam-valve located at or near the steam-bridge in the cab opened; also open water-valve 9 when the lubricator is to be set in operation. The feed-valves are opened and regulated as required by engineer. When steam is admitted into the condenser 101, this fills up with water, which also passes down the water-tube 36 underneath the oil in reservoir 2 the oil is then forced upward, and passes into the oil-tubes 37, one to each side. The oil then surrounds the feed-valves 26, and when these are opened the oil will pass through in drops, raising through the water in sight-feed glasses, and by the check-valve 20 into upper feed-arm 15, and from there through the nozzle 22 into tallow-pipe. In order to equalize the pressure on the top of water in the sight-feed glasses, there are provided equalizing-tubes 7, 7, which convey the steam to upper feed-arm

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* Figs. 102*a*, 103, 107.

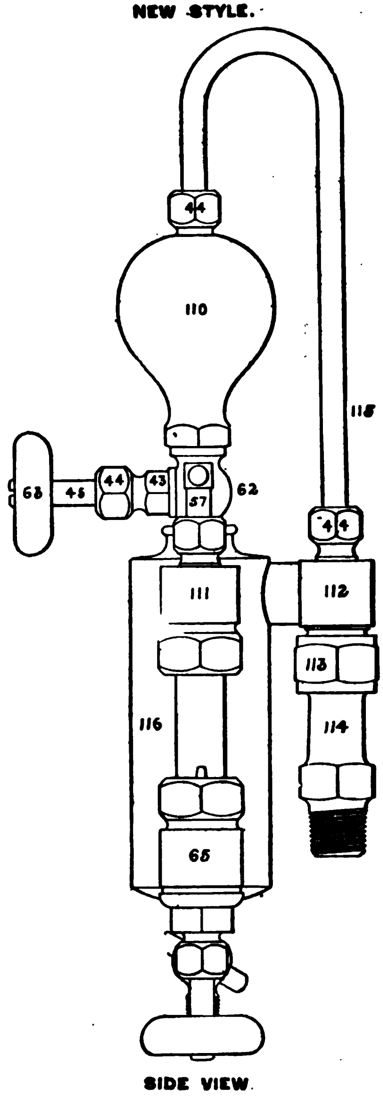

FIG. 102.—THE "DETROIT" NO. 1 IMPROVED AIR-PUMP LUBRICATOR.

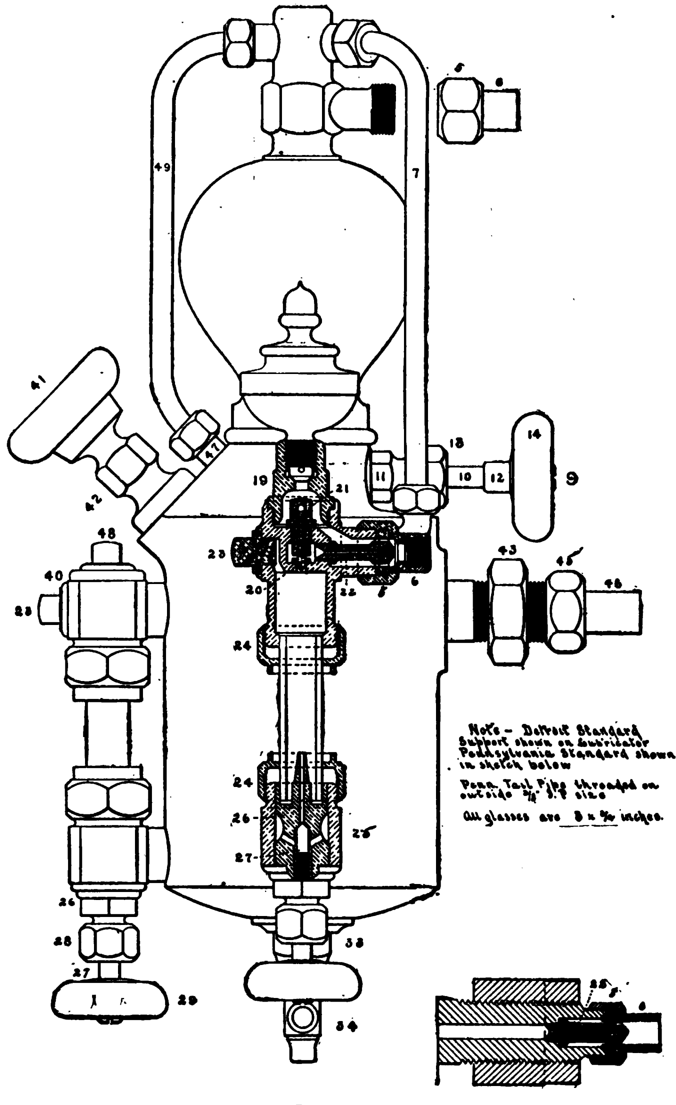
Note – Detroit Standard
Support shown on Lubricator
Pennsylvania Standard shown
in sketch below
Penn. Tail Pipe threaded on
outside ⅜" I.P. size
All glasses are 3 x ¾ inches.

FIG. 102*a*.

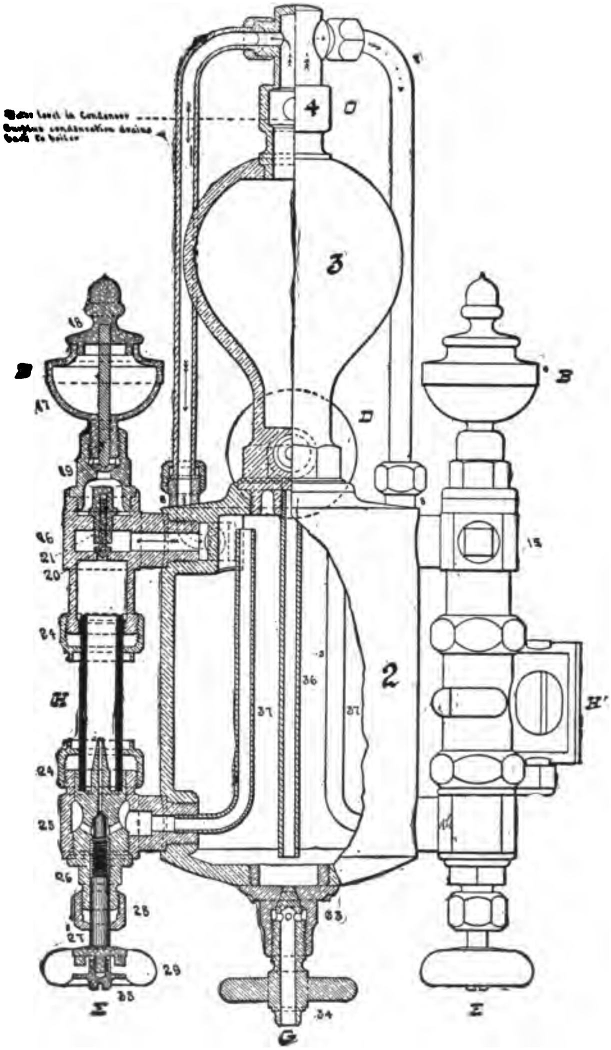

FIG. 103.—THE "DETROIT" NO. 2 IMPROVED LOCOMOTIVE-CYLINDER LUBRICATOR. (Front View.)

DESCRIPTION OF PARTS OF THE DETROIT IMPROVED LOCOMOTIVE-CYLINDER LUBRICATOR.

2. Oil-reservoir.
3. Condenser.
4. Extension-top, complete.
5. Tail-nut.
6. “ -pipe.
7. Equalizing-tubes.
8. Elbow.
9. Water-valve, complete.
10. “ Stem.
11. “ Centre-piece.
12. “ Follower-plate.
13. “ Packing-nut.
14. Wood-handle.
15. Upper Feed-arm, right.
16. “ “ left.
17. Hand-oiler.
18. “ Cover.
19. “ Plug.
20. Check-valve.
21. “ Guide.
22. Nozzle.
23. Water-plug.
24. Packing-nut for Glass.
25. Lower Feed-arm, complete.
26. Feed-valve.
27. “ Stem.
28. “ Packing-nut.
29. “ Stem-handle.
30. Filler-arm.
31. “ -plug.
32. Lower Gauge-arm.
33. Drain-valve.
34. “ Stem.
35. Jam-nut.
36. Water-tube.
37. Oil-tube.
38. Handle-button.

15*a*. Upper Feed-arm, complete, right.

16*a*. Upper Feed-arm, complete, left.

All Glasses, 3 × ⅝.

through a cored passage, and at the same time the steam escaping through the nozzle 22 draws the oil out and forces it into the tallow-pipe, this being the action complete.* The idea in illustrating this lubricator in full and detail, with each part numbered and named, is to try to make it beneficial to the engineer and fireman. In making out work reports the engineer is often at

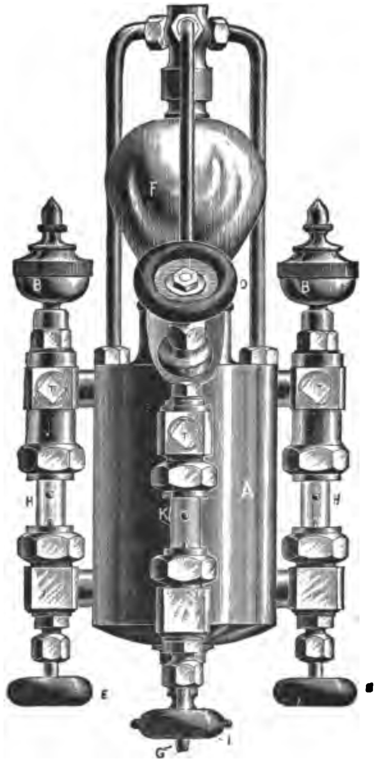

FIG. 104.

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*Figs. 102*a*, 103, 107.

loss for a proper name to give the broken parts, but by referring to the cuts and number as shown, the engineer has a guide which the writer hopes will meet all requirements.

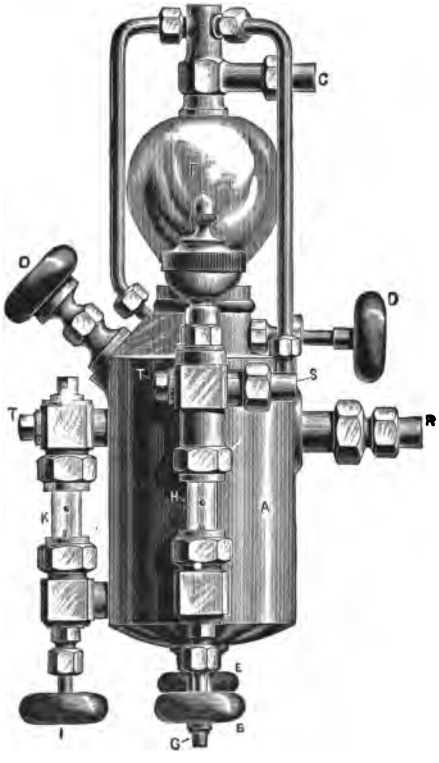

FIG. 105.—THE "DETROIT" NO. 3 TRIPLE LOCOMOTIVE-CYLINDER LUBRICATOR. (Side View.)

The principal points of merit in the Detroit lubricator are as follows: The equalizing-pipes start from a point higher than the steam inlet at *C*, and owing to

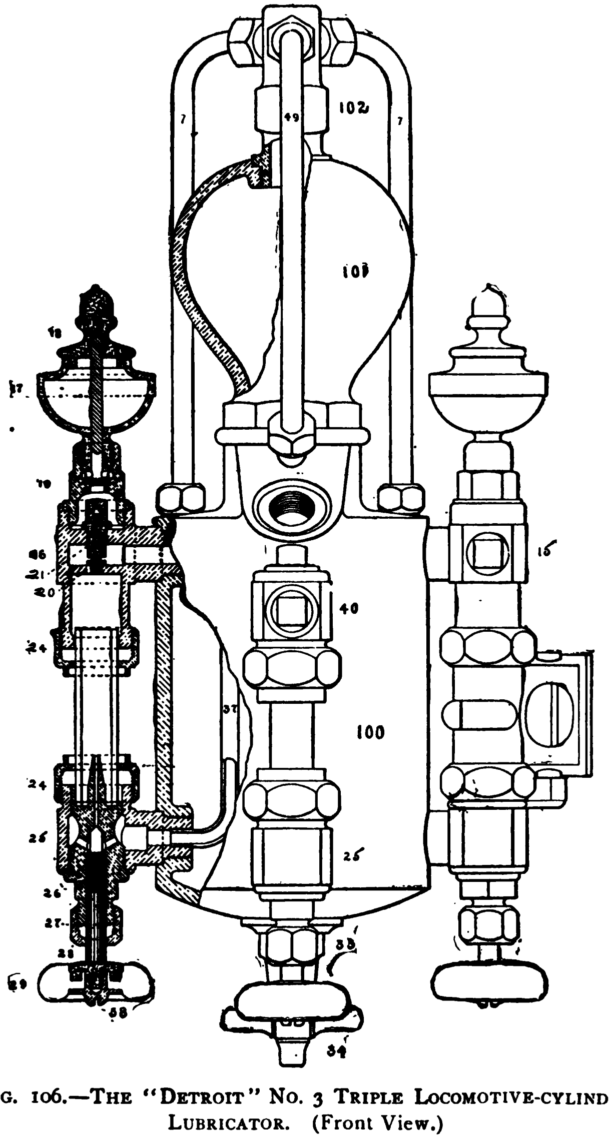

FIG. 106.—THE "DETROIT" NO. 3 TRIPLE LOCOMOTIVE-CYLINDER LUBRICATOR. (Front View.)

DESCRIPTION OF PARTS OF THE DETROIT TRIPLE LOCOMOTIVE-CYLINDER LUBRICATOR.

100. Oil-reservoir.
101. Condenser.
102. Extension-top.
6. Tail-nut.
7. Equalizing-tubes.
8. Elbows.
6. Tail-pipe.
9 Water-valve, complete.
10. “ Stem.
11. “ Centre-piece.
12. “ Follower.
13. “ Packing-nut.
14. Wood-handle.
15. Upper Feed-arm, right.
16. “ “ left.
17. Hand-oiler.
18. “ Cover.
19. “ Plug.
20. Check-valve.
21. “ Guide.
22. Nozzle.
23. Water-plug.
24. Packing-nut for Glass.
25. Lower Feed-arm.
26. Feed-valve.
27. “ Stem.
28. “ Nut.
29. “ Handle.
33. Drain-valve.
34. “ Stem.
37. Oil-tube.
38. Handle-button.
40. Upper Feed-arm to Air.
41. Filler Stopple-handle. Brake-attachment.
42. Filler Stopple.
43. Jamb-nut.
45. Tail-nut to Air-brake Attachment.
46. Tail-pipe to Air-brake Attachment.
48. Check-guide to Air-brake Attachment.
49. Equalizing-tube to Air-brake Attachment.

All Glasses, $3 \times \frac{5}{8}$.

this fact all surplus condensation must drain back into the boiler, and oil and steam only (which are both lubricants) pass through the tallow-pipes to the valves and cylinders. This is of the utmost importance, because better lubrication is secured with a minimum amount of oil, and absolute regularity of feed is obtained.

The equalizing-pipes being on outside of lubricator, leakage or defects in same are readily detected and remedied, all overheating of lubricator is avoided, and a full supply of condensation is always to be depended on.

In case of breakage of sight-feed glass, no steam can escape, as ports are instantly closed automatically by check-valve over sight-feed glass.

The disabling of one side of the lubricator will not affect the satisfactory working of the opposite side.

There is no possibility of cross-feed to one cylinder or into boiler. No movement of throttle-lever will cause any variation of feed. It is as simple in operation as those in use on stationary engines, and effects an enormous saving in oil and wear of machinery. The lubricator is made as a combined air-pump and cylinder-lubricator.

PRESSURE-REGULATORS FOR STEAM-HEATING.

As most all trunk lines have adopted the use of steam-heat for passenger trains, the locomotives are equipped with pressure-reducing valves. The construction and action of these valves should be understood by the engineer and fireman. The valves shown are examples of good reducing-valves, giving good service on standard railroads in the country. A reducing-valve which will shut off steam in case of a failure in operation due to a broken spring. Such a valve is found in the Foster "pressure-regulator," Fig. 108, the action of which is as follows: Steam enters at *A*, and passing through the valve is delivered at *B*. As will be seen, the delivery-pressure entering chamber *K* tends to raise the diaphragm and to close the valve. In opposition to this the compressed spring *H* tends to open the valve. When the valve is in operation there is an equilibrium between these two forces. If the delivery-pressure falls, the pressure on the diaphragm is diminished, and the spring, overcoming the lighter resistance, opens the

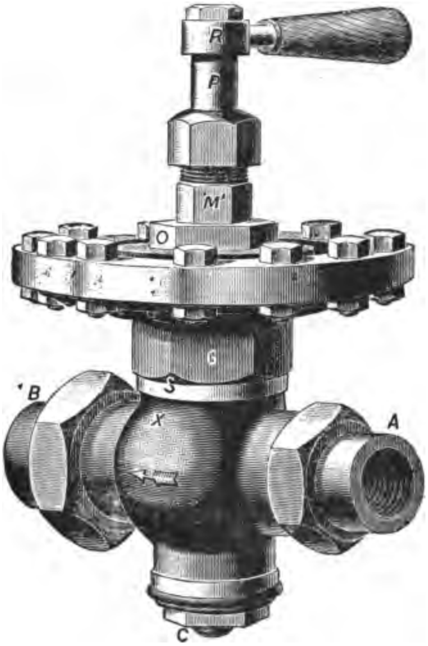

FIG. 107.—FOSTER PRESSURE-REGULATOR.

valve until the equilibrium is again established and the pressure restored; on the other hand, any increased delivery-pressure bearing on the diaphragm overcomes the resistance of the spring and draws the valve toward its seat in proportion to the increased pressure. When the tension of the spring is proportioned to the pressure bearing on the diaphragm, a constant and uniform discharge is insured.

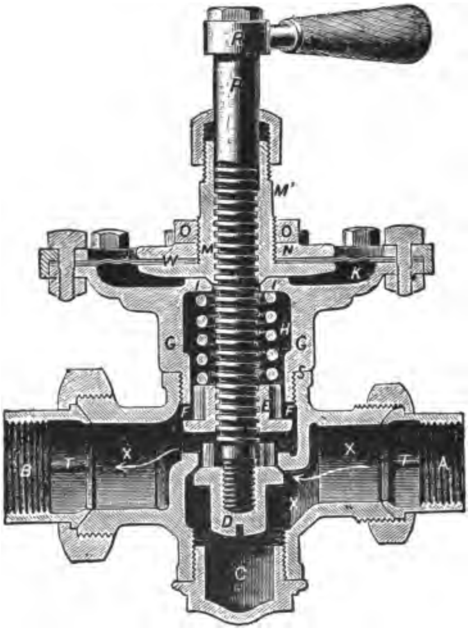

FIG. 108.—FOSTER PRESSURE-REGULATOR.

The spring-nut *E* is threaded on to the spindle, and, having wings which extend into the hexagon-spring chamber *H*, it is prevented from turning with the spindle, but is free to move up and down with it. The flange on the lower side of the spring-nut *E* is a stop to prevent an excessive lift and rupture of the diaphragm. The opening of the valve *D* is regulated by turning the spindle, which is threaded into *M*.

It will be seen from this that if the spring should break the equilibrium would be destroyed, and the delivery-pressure bearing on the diaphragm would close the valve and stop the flow of steam to the train-pipe. In this case it is not only a regulating-valve, but in the event of the spring breaking it becomes an automatic check-valve.

This valve, being an automatic regulator, can control to a nicety the steam admitted to each car, making it possible to carry in the train-pipe enough pressure to get a quick and adequate circulation the whole length of the train, and at the same time to carry a low-pressure in each car. This is the ideal condition. The parts are named so clearly in the descriptions, that in case the engineer has a report to make on the work slip, he will not be at a loss for a name for the different parts to be repaired on either of these regulators.

THE MASON REDUCING-VALVE FOR LOCOMOTIVES.

This valve is designed to automatically reduce and maintain an even steam-pressure for heating cars from the locomotives. It is placed in the steam-supply pipe leading from the boiler to the heating system, and regulates the amount of steam passing to the system, allowing only sufficient steam to maintain the desired pressure. These reducing-valves are fitted with union connections or tapped ends, in any size preferred. They are thoroughly reliable, and are the standard used on over one hundred railroads. [A good reason for showing this valve.—AUTHOR.]

Description. (See Sectional View.)—The principle on which the Mason Reducing-valve works is that of an auxiliary-valve 11 controlled by the low-pressure in the heating system, through the medium of a metal diaphragm, and admits steam from the initial side of the valve through a port to operate a piston 17, which in turn opens the main-valve 16, and admits steam to the system. By referring to sectional view it will be seen that the steam enters the valve at the side marked "inlet," a small portion of it passing up through the auxiliary-valve 11. This valve 11 is forced open by the compression of the large spiral spring 8, acting on the button 10 through the diaphragm, so that in opening the valve 11 the diaphragm is also forced down. As soon as the valve 11 is opened steam passes through and into port *N* under piston 17. By raising this piston 17 the main-valve 16 is opened against the initial pressure, since the area of valve 16 is only one half of that of piston 17. Steam is thus admitted to the system. When the pressure in the system has reached the required point,

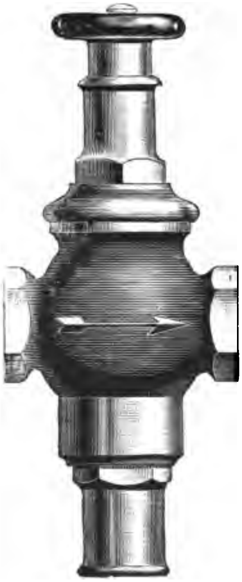
FIG. 109.—MASON REDUCING-VALVE.

which is determined by the spring 8, the diaphragm is forced upward by the low pressure, which passes up through port *XX*, to chamber *OO*, under the diaphragm, allowing valve 11 to close, shutting off the steam from piston 17. The main-valve 16 is now forced to its seat by the initial pressure shutting off steam from the system, and pushing the piston 17 down to the bottom of its stroke. The steam beneath this piston 17 exhausts freely around it (the piston being fitted loosely for this purpose), and passes off into the system. It will be seen from this that when the pressure in the heating system has reached a predetermined point the flow of steam will be automatically checked, and when the pressure is slightly reduced the valve will again open and supply the required amount of steam. The piston 17 is fitted with a dash-pot 18, which prevents chattering or pounding when the pressure is suddenly reduced.

Directions.—Place the valve vertically in the steam-supply pipe. The steam should flow through the valve in the direction indicated by the arrow cast in the side. Before connecting the valve the pipes should be thoroughly blown out, in order to expel all dirt and chips. If the piping is new, steam should be allowed to flow through for some little time, so as to burn off all the oil or grease which may be in it.

When ready to let on steam, turn the wheel at top of the valve in the same direction as you would to open a globe-valve. Time must be allowed for the system to fill, before the required pressure is obtained.

If the valve should not maintain a low pressure, it will probably be due to the fact that some dirt or chips from the piping have lodged in the seat of the valve 16.

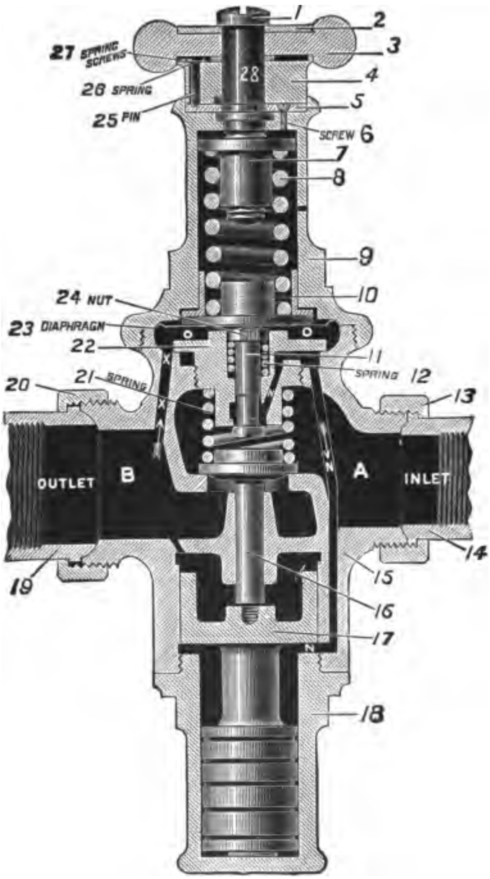

FIG. 110.—MASON REDUCING-VALVE. (Sectional View.)

To take the valve apart, the tension on the diaphragm spring 8 must first be removed by turning the wheel as far as it will go in the direction taken by the hands of a watch. Then unscrew the spring-case 9, and remove the button 10 and the diaphragm; also remove the cap 22, which contains the auxiliary-valve. The threaded rod which accompanies each valve can then be screwed into the valve-disk 16, which should work easily. Pull out this valve and clean the seat. Then insert the rod through the valve-stem hole, screw it into the piston 17, and see if it works up and down easily. It will not be found possible to raise and lower the piston 17 suddenly, as the dash-pot 18 will restrain it. If the piston 17 is found to be stuck fast, remove the dash-pot 18 at the bottom of the valve, pull out the piston and clean it with fine emery-cloth, being careful to wipe off all emery before replacing. Before replacing the cap 22, examine the small auxiliary-valve 11, and see that it is tight, and free from dirt. Be sure that the diaphragm 23 is perfectly clean, also that there is no dirt where it makes its seat.

The wheel is made self-locking in any position by means of a steel locking-pin 25, which is forced by a spring into any one of twelve recesses in a hardened steel plate 5. We advise removing the valve during the summer. Before replacing, thoroughly clean and oil all the parts.

CHAPTER XIII.*

BRAKES, AIR-PUMPS, VALVES, PUMP-GOVERNORS, AND WESTINGHOUSE BRAKES.

THE Westinghouse Improved Quick-action Automatic Brake consists of the following essential parts:

1. THE STEAM ENGINE AND PUMP, which furnishes the compressed air.

2. THE MAIN RESERVOIR, in which the compressed air is stored.

3. THE ENGINEER'S BRAKE AND EQUALIZING-DISCHARGE VALVE, which regulates the flow of air from the main reservoir into the brake-pipe for releasing the brakes, and from the main train or brake pipe to the atmosphere for applying the brakes.

4. THE MAIN TRAIN OR BRAKE PIPE, which leads from the main reservoir, to the engineer's brake and equalizing-discharge valve, and thence along the train, supplying the apparatus on each vehicle with air.

5. THE AUXILIARY RESERVOIR, which takes a supply of air from the main reservoir, through the brake-pipe, and stores it for use on its own vehicle.

6. THE BRAKE-CYLINDER, which has its piston-rod attached to the brake-levers in such a manner that,

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* This chapter is taken from the Instruction-book of the Westinghouse Air-brake Company.

when the piston is forced out by air-pressure, the brakes are applied.

7. THE IMPROVED QUICK-ACTION AUTOMATIC TRIPLE-VALVE, which is suitably connected to the main train-pipe, auxiliary reservoir, and brake-cylinder, and is operated by the variation of pressure in the brake-pipe (1) so as to admit air from the auxiliary reservoir (and under certain desirable conditions, as will be explained hereafter, from the train-pipe) to the brake-cylinder which applies the brakes, at the same time cutting off communication from the brake-pipe to the auxiliary reservoir, or (2) to restore the supply from the train-pipe to the auxiliary reservoir, at the same time letting the air in the brake-cylinder escape, which releases the brakes.

8. THE COUPLINGS, which are attached to flexible hose and connect the train-pipe from one vehicle to another.

9. THE AIR-GAUGE, which, being of the duplex pattern, shows simultaneously the pressures in the main reservoir and the train-pipe.

10. THE PUMP-GOVERNOR, which regulates the supply of steam to the pump, stopping it when the maximum air-pressure desired has been accumulated in the train brake-pipe and reservoirs.

The automatic action of the brake is due to the construction of the triple-valve, the primary parts of which are a piston and slide-valve. A moderate reduction of air-pressure in the train-pipe causes the greater pressure remaining stored in the auxiliary reservoir to force the piston of the triple-valve and its slide-valve to a position which will allow the air in the auxiliary reservoir to pass directly into the brake-cylinder and apply the brake.

A sudden or violent reduction of the air in the train-pipe produces the same effect, and in addition to this causes supplemental valves in the triple-valve to be opened, permitting the pressure in the train-pipe to also enter the brake-cylinder, augmenting the pressure derived from the auxiliary reservoir about 20 per cent, producing practically instantaneous action of the brakes to their highest efficiency throughout the entire train.

When the pressure in the brake-pipe is again restored to an amount in excess of that remaining in the auxiliary reservoir, the piston and slide-valve are forced in the opposite direction to their normal position, opening communication from the train-pipe to the auxiliary reservoir, and permitting the air in the brake-cylinder to escape to the atmosphere, thus releasing the brakes.

If the engineer wishes to apply the brakes, he moves the handle of the engineer's brake-valve to the right, which first closes the port, retaining the pressure in the main reservoir, and then permits a portion of the air in the train-pipe to escape.

To release the brakes, he moves the handle to the extreme left, which allows the air in the main reservoir to flow freely into the brake-pipe, restoring the pressure and releasing the brakes.

A valve called the Conductor's Valve is placed in each car, with a cord running throughout the length of the car, and any of the trainmen, by pulling this cord, can open the valve, which allows the air to escape from the train-pipe, applying the brake.

When the train has been brought to a full stop in this manner the valve should be closed.

Should the train break in two, the air in the brake-pipe escapes, and the brakes are applied instantaneously to both sections of the train. The brakes are also automatically applied should a hose or pipe burst. It will therefore be seen that *any reduction of pressure in the train-pipes applies the brakes*—which is the essential feature of the automatic brake.

An angle-cock is placed on each end of the train-pipe, and is closed before separating the couplings, thus preventing the application of the brakes when cars are uncoupled.

A stop-cock is placed in the branch-pipe leading from the main train-pipe to the quick action triple-valve, and one in main train-pipe near the engineer's brake-valve, and within convenient reach of the engineer. The former is for the purpose of cutting out or rendering inoperative the brake on any particular car which may have become disabled through damage, and the latter for cutting out the engineer's brake-valve upon all but the leading engine, where two or more engines are coupled in the same train.

It is desirable to use the old-style plain automatic triple-valve for locomotive driver and tender brakes, and its illustration in this connection will be noted in Plate I, Fig. 1, and in greater detail in Figs. 3, 4, and 4a.

Mechanically, the engineer's brake and equalizing-discharge valve provides for a lack of skill in so far as such devices can be made automatic; but it is essential that the engineer should be possessed of a degree of skill and judgment which will enable him to operate the brakes of his train in a judicious manner, by using them with care and moderation in making ordinary stops, and only in cases of actual emergency to make a quick application.

The attention of the engineer is therefore especially directed to the description of the new engineer's brake and equalizing-discharge valve, and the instructions relating to the proper method of operating the quick-action automatic brakes.

THE AIR-PUMP.

The construction of the air-pump is clearly shown in cross-section in plate 2, Fig. 111. A steam-cylinder 3 and air-cylinder 5 are joined together by a centre-piece 4, which forms the bottom head of the steam-cylinder and the top head of the air-cylinder, while suitable stuffing-boxes 56 therein encircle the piston-rod 10, the lower end of which is attached to air-piston 11, and the upper end to the steam-piston, each of which is provided with suitable packing-rings.

Suitably arranged valves in the walls of the steam-cylinder 3 and its upper head 2, to which further reference will be made, admit steam alternately above and below the steam-piston 10, forcing it upward and downward, giving a similar movement to the air-piston; while air from the outside atmosphere is drawn alternately through the air-inlets and receiving-valves 31 and 33 and forced under pressure through the dis-

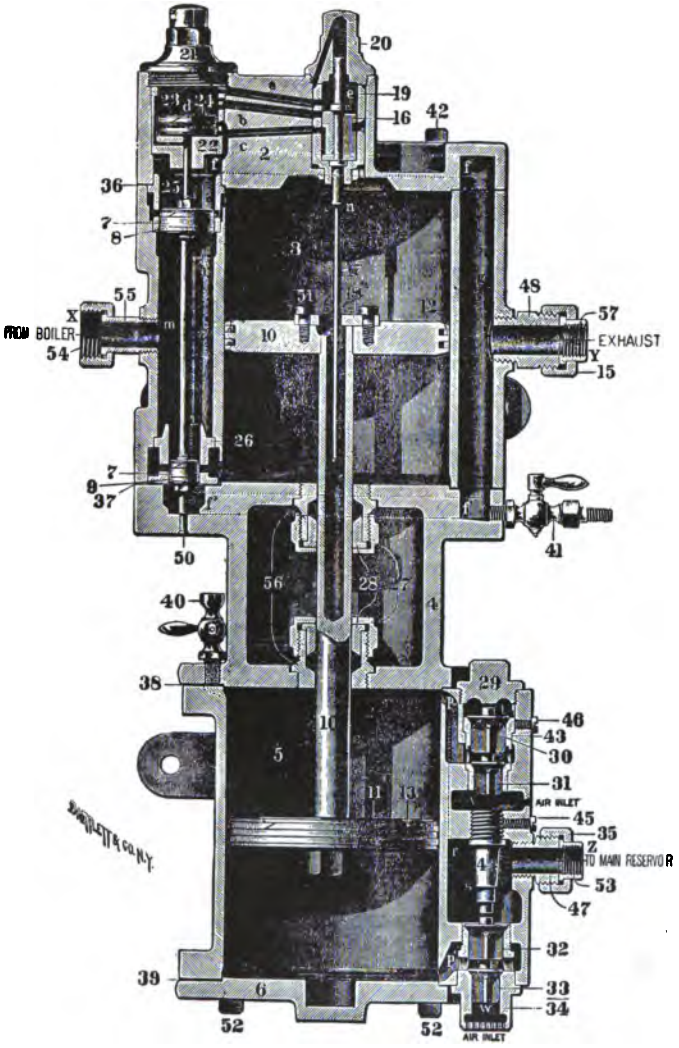

d
e
b
c
f
n
X
FROM BOILER
m
EXHAUST
Y
f
AIR INLET
Z
TO MAIN RESERVOIR
w
AIR INLET
BARTLETT & CO. N.Y.

FIG. 111.

charge-valves 32 and 30, into chamber *S*, and thence to the main reservoir through pipes connecting at the union swivel 53.

The main steam-valve *7* is formed of two pistons of unequal diameter, mounted upon opposite ends of a rod, the upper one occupying cylindrical bushing 25, and the lower bushing 26, each of these bushings having two series of port-holes for the admission of steam to and its exhaust from the steam-cylinder by a reciprocating movement of the main-valve.

Connection with the source of steam-supply is made to the union-nut 54, and with steam in chamber *m*. The tendency of the main-valve, on account of the greater diameter of its upper piston, is to move upward, thus providing for its upward movement and for the admission of steam to the upper side of the steam-piston 10, and its exhaust from the lower side.

The opposite or downward movement is accomplished at the proper moment by the combined action of steam-pressure upon the upper surface of the lower piston of the main-valve and reversing-piston 23, the stem of the latter extending through the bushing 22, in which it operates, and bearing upon the top of the main steam-valve. Pressure upon the upper side of reversing-piston 23 is regulated by a small slide-valve 16 in the central chamber *e*, of the upper steam-cylinder head 2, to which steam-pressure is conducted from chamber *m* through port *h*.

This valve is given motion by a rod 17, which extends through bushing 19 in the upper head and into the hollow main-piston rod 10, and is provided with a button-head on its lower end, and a shoulder *n* just below the top head; the plate 18 on the steam-piston alternately strikes this shoulder and button-head as the steam-piston 10 approaches the top or bottom head of the steam-cylinder.

Steam from the boiler being admitted to chamber *m* forces the main-valve upward, which uncovers the lower series of ports in bushing 25, and entering the steam-cylinder above the main-piston 10 drives it downward, while steam used on the previous upward stroke is discharged from the under side of the lower main-valve piston through the lower series of ports in bushing 26, which were also uncovered by this upward movement of the main-valve, thence through a suitably arranged passage *f*, shown in dotted lines, communicating with exhaust-chamber *g*, whence it is discharged by a pipe connected at union swivel 57, through the smoke box and stack to the atmosphere. As the main-piston reaches the termination of its downward stroke, plate 18, striking the button-head on the lower end of the reversing-valve rod 17, draws the rod and its valve 16 downward, uncovering port *a* in the upper head and admitting steam above reversing-piston 23, which forces it and the main-valve 7 downward to the position shown in the cut, and permits steam from above the main-piston 10 to be discharged through the upper series of port-holes in bushing 25, thence through passage *ff* to exhaust-chamber *g* and the atmosphere, while live steam is admitted from chamber *m* through the upper series of ports in bushing 26 to the under side of main-piston 10, driving it upward until plate 18 strikes the shoulder *n* of reversing-rod 17, which pushes valve 16 upward, and brings the small exhaust-cavity in its seat opposite ports *b* and *c*, exhausting the pressure from above reversing-piston 23 into exhaust-passage *ff*, which permits the main-valve to again move upward as previously described.

The upward movement of air-piston 11 causes the lower receiving-valve 33 to lift, and air to be drawn through the series of inlet-ports in the under side of the valve-chamber cap 34, thence past the valve and through port *p'* to the cylinder; the downward movement of the air-piston closes receiving-valve 33, and compresses the air contained in the cylinder to a point in excess of that which may already be stored in the main reservoir, which lifts discharge-valve 32, and permits the compressed air to flow into chamber *s* and to the main reservoir through pipes connected at union swivel 53. The downward movement of the air-piston similarly causes the air to be drawn into the upper end of the cylinder through the upper air-inlet ports to chamber *v* through upper receiving-valve 31 and passage *p*.

The air on this side of the air-piston in being compressed during the upward stroke closes the receiving-valve, and raising upper discharge-valve 30 is forced into chamber *t*, and thence through communication port *r* to chamber *s* and the main reservoir.

The lift of the receiving-valves should be $\frac{5}{32}$ of an inch, and that of the discharge-valves $\frac{1}{8}$.

It is most important that the prescribed amount of lift of air-valves be maintained, and if exceeded by wear from action, which will ultimately occur, should not be permitted to become excessive, in which event valves and seats may both be ruined by pounding upon each other, while prompt attention may save both, and prevent disagreeable pounding.

In renewing bushing 43 the shoulders upon which it rests in position should be carefully ground in to prevent leakage of air past these, then adjust set-screw 46, when cap-nut 29 may be screwed firmly, but not harshly, upon it.

With 125 pounds steam-pressure, the 8-inch pump when in good condition will compress 0 to 70 pounds pressure of air in a standard main reservoir 26½ inches in diameter by 34 inches long (outside measurement), about 9 cubic feet capacity in 88 seconds, and from 20 to 70 pounds in 62 seconds.

The efficiency of the pump and its condition may therefore be readily ascertained at any time desired.

If other reservoirs are used than the dimensions given, the duty may be calculated in exact proportion.

THE QUICK-ACTION TRIPLE-VALVE.

A large view of the triple-valve in cross-section is shown in Fig. 112, a transparent view of the slide-valve in Fig. 113, and of the slide valve seat in Fig. 114, to which references will be made in the following explanation of its purpose and functions.

The quick-action triple-valve is wholly automatic in principle, that feature existing in the construction of the plain automatic triple-valve by which its mechanism could be "cut out" or made inoperative, or permitting the use of the "straight-air" or non-automatic form of brake, being entirely omitted.

As its name implies, the quick-action triple-valve is designed to facilitate rapidity of action of the brakes upon railway trains, particularly those of considerable length, where desired.

Simultaneous action, as nearly as possible, is quite necessary to avoid shock consequent upon link or drawbar slack between cars. Such action, however, is only necessary in an emergency, its ordinary action for service applications of the brake being in entire harmony with that of the old-style triple-valves, either method of application being entirely dependent upon the rapidity with which the air is discharged from the train-pipe, and consequently under the control of the engineer.

Under each car in the main train-pipe is a drain-cup forming a tee, from which a branch-pipe extends to the triple-valve, to which it is connected at *A*, and a stop-cock is placed in this branch-pipe for the purpose of rendering inoperative the brakes upon any particular car when occasion requires, by reason of accident to the brake gear or apparatus leaving the main train-pipe unobstructed to supply air to the remaining vehicles.

The opening *B* communicates with a chamber in the cylinder-head, from which a pipe leads to the auxiliary reservoir. The opening *C* communicates with a port in the cylinder-head through which air is conducted to and from the brake-cylinder.

Air from the main reservoir on the engine, being discharged into the train-pipe by the operation of the engineer's brake-valve, enters triple-valve at *A*, and passes thence through ports *ee* and *gg*, to piston-chamber *h*, forcing the piston 4 to the normal position shown, which it occupies when brakes are released, uncovering feed-port *i*, permitting the air to pass by the piston, thence through port *k* to chamber

QUICK ACTION TRIPLE VALVE.

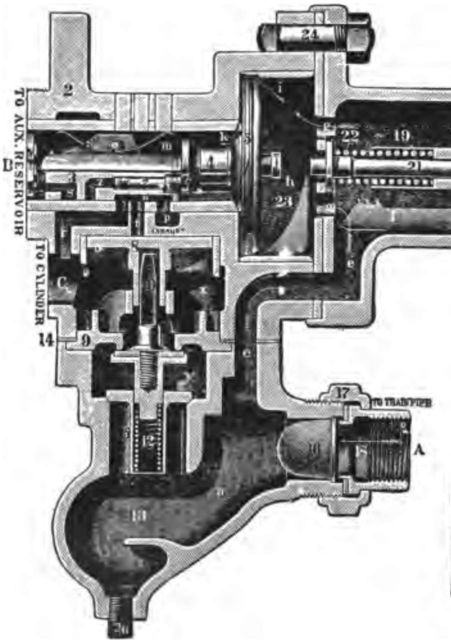


FIG. 112.

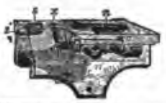


FIG. 113.

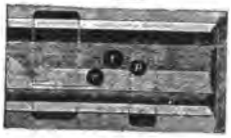


FIG. 114.

m, occupied by the slide-valve 3, from which it has free egress at opening *B* to the auxiliary reservoir, charging the latter to the same pressure as that in the train-pipe.

That portion of the stem of the piston 4 between the shoulders *u* and *c* is semicircular in form, and passes between two flanges of the slide-valve 3, the length of the latter being slightly less than the distance between these shoulders, permitting a limited movement of the piston, without moving the slide valve.

The arrangement of the ports in the latter will be clearly understood by reference to transparent view in Fig. 113. It will also be observed that a corner of the slide-valve opposite ports *s* and *z* is cut away, for reasons that will appear later.

A graduating-valve, 7, is attached to and moves with the stem of the piston 4, and extends into a suitably made recess in the slide-valve, opening and closing port *z* in the slide-valve.

Under ordinary conditions of operating the brakes, by a slight reduction of pressure in the train-pipe the movement of piston 4 in cylinder *h* is limited to the distance between the knob *j* and the end of the graduating-stem 21, the spring 22 resisting further movement, but which may be compressed by the piston, permitting the latter to traverse the entire length of the cylinder *h*, if a rapid discharge of 10 or 12 pounds pressure or more is made from the train-pipe. To apply the brakes gently, a slight reduction of 6 to 8 pounds pressure in the train-pipe is made, causing the greater pressure remaining in the auxiliary reservoir, with which chamber *m* is in constant communication, to force piston 4 to the right, closing feed-port *i*, and moving the graduating valve away from its seat in port *z* until the shoulder *u* on the piston-stem, engaging the slide-valve 3, moves it with the piston until the latter is stopped in its traverse, by knob *j* meeting the graduating-stem 21, the spring 22 resisting further movement. In this position port *z* is opposite port *r* in the valve-seat, and air from the auxiliary reservoir passes into the brake-cylinder through ports *w*, *z*, *r*, *r* and *C*, forcing the piston outward and applying the brakes.

The pressure in the auxiliary reservoir having now been reduced by expansion into the brake-cylinder to an amount slightly less than that in the train-pipe, piston 4 is forced to the left and graduating-valve 7 to its seat, closing port *z*, the slide-valve remaining stationary, retaining the pressure in the brake-cylinder.

Further reductions of pressure in the train-pipe, as may be desired to apply the brakes with greater force, cause the piston 4 to again move to the right against graduating-stem 21, pulling graduating-valve 7 from its seat, admitting additional pressure from the auxiliary reservoir to the brake-cylinder until entirely equalized in each, or to about 50 pounds, from an original pressure of 70 pounds in the auxiliary reservoir. This effect is caused by a reduction of air-pressure in the train-pipe of about 20 pounds, from which it will be seen that any further reduction is a waste of air, and that the force with which the brakes may be applied is proportionate to the reduction of pressure in the train-pipe within this limit.

The brakes are released by admitting pressure to the train-pipe, which forces piston 4 to the left to the position shown, permitting pressure in the brake-cylinder to escape to the atmosphere through ports *c*, *r*, *r* and exhaust-ports *n* and *p*, the latter being cored to the atmosphere around the valve body.

The action of the brakes just described is that used in ordinary station stoppages, and is termed a "service application," and is caused, as will have been observed, by a gradual discharge of pressure from the main train-pipe at the engine.

To apply the brakes with their full force, a quick reduction of the pressure in the train-pipe of 10 to 12 pounds is made, causing the piston 4 to move through the entire length of its cylinder *h*, compressing graduating-spring 22, and bringing port *s* in the slide-valve opposite port *r* in its seat, admitting pressure from the auxiliary reservoir to the brake-cylinder, at the same time the removed corner of the slide-valve 3, before referred to, uncovers port *t* in its seat, admitting auxiliary-reservoir pressure above piston 8, forcing it downward, and emergency-valve 10 from its seat; while train-pipe pressure, lifting valve 15, rushes to the brake-cylinder through the openings made, in a large volume, uniting with that from the auxiliary reservoir, giving a pressure on the piston of about 60 pounds per square inch, from 70 pounds auxiliary-reservoir and train-pipe pressure, or about 20 per cent greater than from a service application of the brakes.

The check-valve 15 closing when the pressure is equalized, prevents pressure from the brake-cylinder re-entering the train-pipe. A restoration of pressure in the train-pipe releases the brakes, as already described, port *t* being brought into communication with exhaust-port *n* of the slide-valve, permitting the air used in forcing piston 8 downward to escape into the atmosphere, and spring 12 then restores emergency-valve 10 to its seat.

This action of the brake apparatus, as will have been noted, causes a local reduction of train-pipe pressure under each car, by discharging this air into the cylinder for braking purposes, instead of having it wholly pass to the atmosphere at the engine, as was necessarily the case with the plain form of the automatic brake apparatus, economizing the use of air-pressure and producing practically instantaneous action of the brakes throughout an indefinite length of train ; but they should be used in this manner in cases of emergency only.

To prevent the application from a slight reduction of pressure caused by leakage in the train-pipe, an oval groove is cut in the bore of the car-cylinder $\frac{9}{64}$ of an inch in width and $\frac{5}{64}$ of an inch in depth, and of such length that the piston must travel three inches before the groove is covered by the packing leather.

A small quantity of air, such as results from a leak, passing from the triple-valve into the brake-cylinder, may have the effect of moving the piston slightly forward, but not sufficiently to close the groove, which permits the air to flow, to the atmosphere past the piston. If, however, the brakes are applied in the usual manner the piston will be moved forward, notwithstanding the slight leak, and will cover the groove. It is very important that the groove shall be of the dimensions given.

The triple-valve should be drained occasionally of any moisture that may accumulate, by the removal of the bottom plug.

In an "emergency" action of the brakes, when, as previously stated, air from the train-pipe is vented into the brake-cylinder, the strong current of air toward the triple-valve carries with it any foreign matter in the air-pipes, and this lodging in the conical strainer 16, at the union of the branch-pipe and the triple-valve, may clog the meshes of the strainer and prevent the free passage of air, and should therefore be cleaned occasionally, but this may be largely avoided if the hose, when not coupled to that on adjoining vehicles, is placed in its dummy coupling and the air-pipes are carefully blown out with steam previous to their erection on the car.

Should a continuous leak manifest itself at the exhaust-port of the triple-valve, or the pressure-retaining valve, it will usually be found to be due to the presence of dirt on the seat of the emergency-valve 10, which should be cleaned.

On account of slight differences in sizes of ports, triple-valves intended for freight or passenger car brakes must not be used in the opposite service.

The passenger-car triple-valve having a letter *P* cast upon its body, may be readily distinguished from that intended for freight service.

THE PLAIN AUTOMATIC TRIPLE-VALVE.

A perspective view of the plain automatic triple-valve and locomotive-tender brake apparatus is shown in Fig. 115, and cross-sections of the triple-valve in Fig. 116, which will clearly show its construction.

It is desirable that this triple-valve be perpetuated for use witn locomotive driving-wheel and tender brakes, to give a slightly slower action to the brakes thereon in cases of emergency action of the quick-action apparatus on the cars.

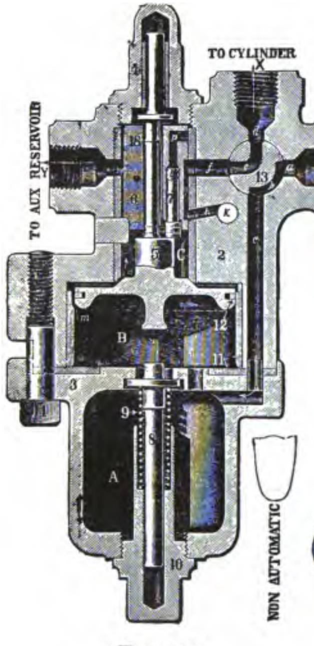


FIG. 115.

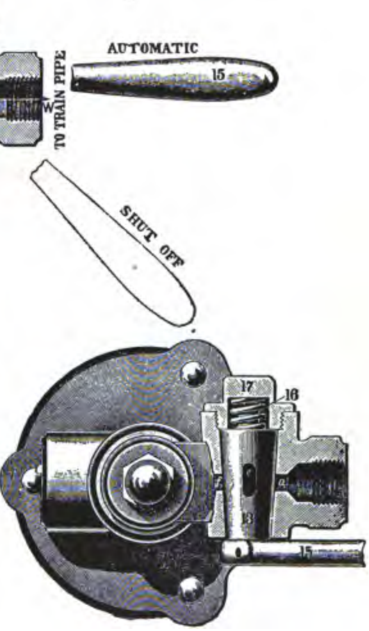


FIG 116.

The construction and operation of the plain automatic triple-valve is substantially the same as that of the quick-action form, the quick-action valves being omitted, and pressure used only from the auxiliary reservoir in applying the brakes, and will not, therefore, require specific description.

As constructed formerly, the handle, 15, could be turned from a horizontal position, which it occupies when the brakes are operated as automatic, to a vertical position, permitting the use of the non-automatic brake; but as this is now practically obsolete, a lug is cast upon this handle which permits it to be turned only to an intermediate position, in which the brakes are inoperative or shut off on that particular vehicle.

To drain the cup 3 of moisture, slack the bottom nut 10 a few turns, let any water escape, and screw it up again. A tender drain-cup should invariably be located in the main train-pipe on the tender to catch and retain moisture, which would otherwise pass to the train-brake apparatus. A cock in this cup readily provides for letting out the moisture, which should be done frequently.

THE ENGINEER'S BRAKE AND EQUALIZING-DISCHARGE VALVE.

The Engineer's Brake and Equalizing-discharge Valve, sectional cuts of which are shown on Figs. 117 and 118, and a plate view in Fig. 119, with the cap-nut 12 and rotary-valve 13 removed, is a device designed especially to assist the engineer in operating train-brakes in a more perfect manner than has hitherto been possible with the three-way cock or brake-valves formerly used for this purpose, without considerable personal skill from the operator.

It is of the greatest importance to perfect train-braking that gradual exhaust or discharge of air pressure from the train-pipe should be made in applying the brakes under ordinary conditions of station stopping, and a gentle closing or stoppage of this exhaust in order to thoroughly equalize the pressure remaining in the train-pipe, thus preventing the release of some of the front brakes of the train, which may occur, particularly on long trains, by the abrupt opening and closure of the ordinary three-way cock, which causes a violent surge of air from the rear to the front end of the train, affecting the brakes as stated.

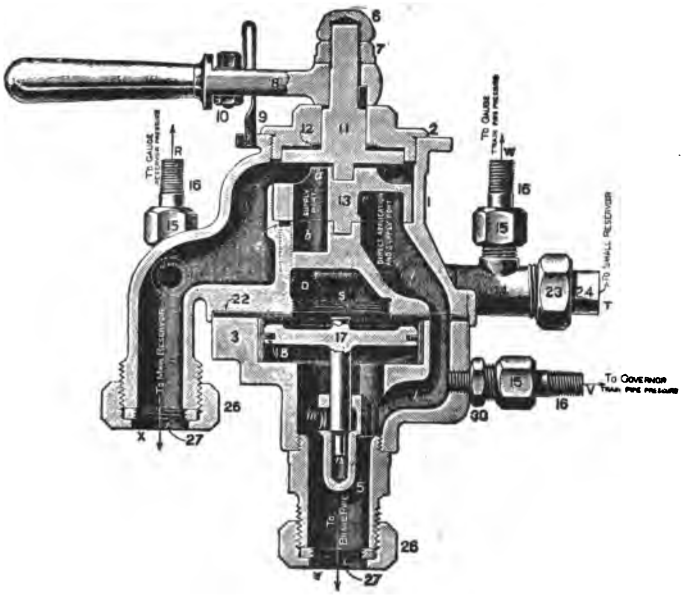

6
7
8
10
9
12
11
2
To Gauge Reservoir Pressure
R
16
15
To Gauge Train Pipe Pressure
W
16
15
To Small Reservoir
a
Supply Port
b
13
Direct Application and Supply Port
1
D
5
23
24
T
22
3
17
18
To Main Reservoir
To Governor Train Pipe Pressure
V
15
16
30
26
X
27
5
To Brake Pipe
26
Y
27

FIG. 117.

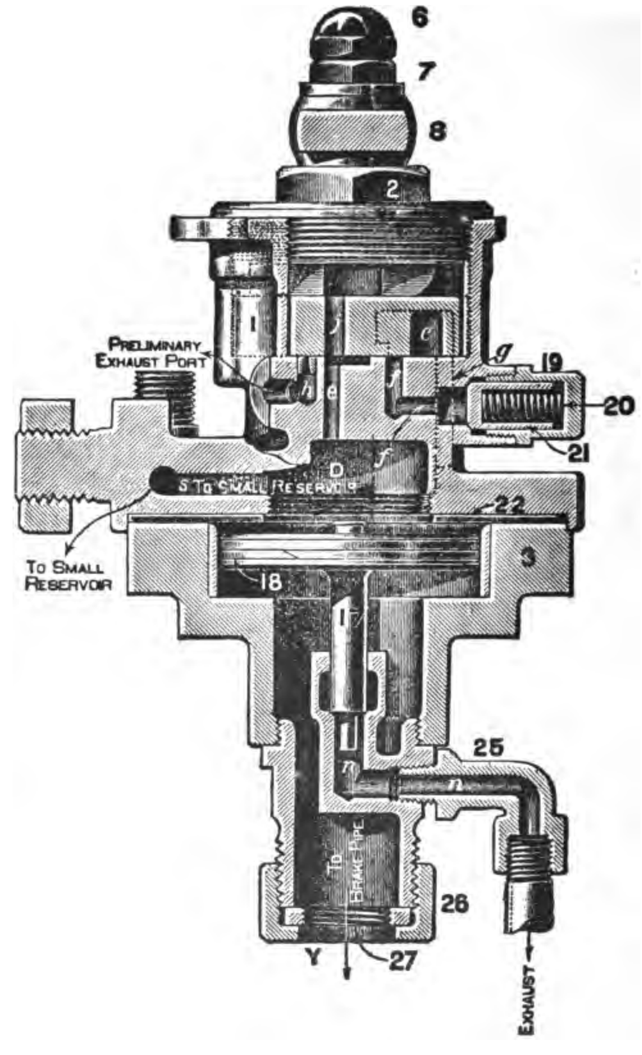

6
7
8
2
1
j
c
g
19
20
21
PRELIMINARY EXHAUST PORT
h
e
f
f
D
S TO SMALL RESERVOIR
22
TO SMALL RESERVOIR
3
18
17
n
25
n
TO BRAKE PIPE
26
Y
27
EXHAUST

FIG. 118.

The brake-valve here illustrated entirely prevents this, and *mechanically measures the volume of air required to be discharged from the train-pipe and limits the rate of its discharge when applying the brakes for ordinary stoppages*, and is equally efficient on short or long trains.

Large openings are provided in its construction for the instantaneous application of the brakes in an emergency.

It is absolutely essential in operating the brakes upon long trains, and is of great importance on short ones, to store a pressure of air in the main reservoir on the engine of twenty to twenty-five pounds greater than train-pipe and auxiliary-reservoir pressure, which will, when discharged into the train-pipe, insure a prompt release of all the brakes.

A full set of engine-brake fixtures includes a pressure-gauge having two sets of works, and two indicators (red and black) on a single dial, which shows at a glance the presence respectively in the main reservoir and train-pipe, the connecting pipes being attached to the brake-valve at *R* and *W*. The air-pipe to the pump-governor should be connected at *V*, the main reservoir-pipe at *X*, and train-pipe at *Y*.

By preparing a diagram similar to Fig. 120, representing the rotary-valve 13 and handle 8, of tracing-cloth or other transparent material, cutting the ports *a* and *j* out of the diagram on their boundary-lines to show through openings, and then reversing same and placing it upon the seat of the valve, Fig. 119, where it may be rotated at will on its centre, the explanation following may be made clear.

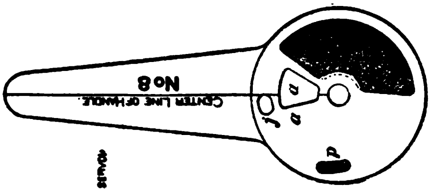


FIG. 120.

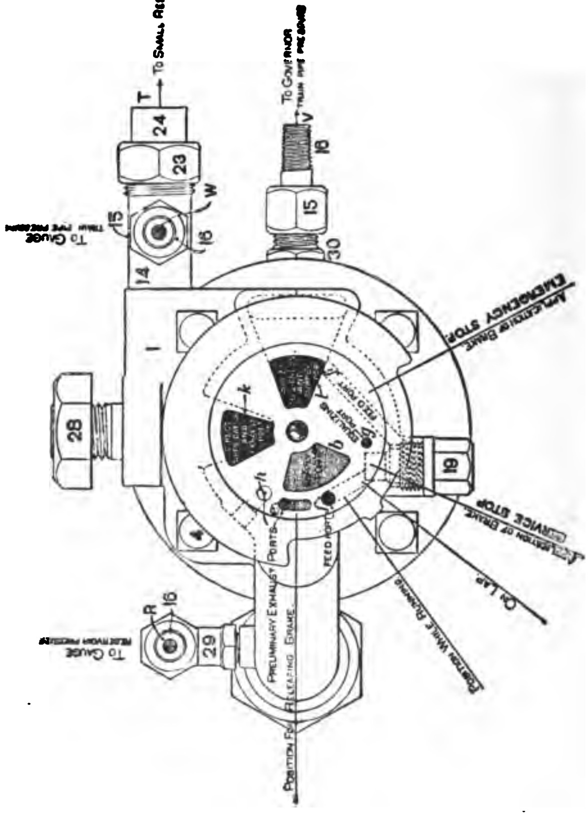


FIG. 119.

By reference to cuts of the valve, it will be seen that movement of the handle 8, on which is located a spring 9 for guiding it to position, operates "rotary-valve 13" upon its seat, opening and closing the various ports as required.

When the handle 8 is in "position for releasing the brake," air from the main reservoir entering the brake-valve at *X* passes through "supply-ports" *a* and *b*, thence upward into cavity *c*, in the under surface of the rotary-valve 13, then through "direct application and supply-port" 1 to the pipe at *y*.

While yet in this position, port *j* in the rotary-valve and port *e* in the seat are in communication, and air passes into chamber *D*, above piston 17, thence through port *s* to a small reservoir, which is usually suspended under the right running-board of the engine, pipe-connections being made therewith at *T*. This reservoir serves the purpose of increased volume of space to chamber *D*.

The handle 8 now being placed in "position while running," *direct* communication between the train-pipe and main reservoir ceases, and port *j* is brought opposite feed-port *f*, through which main-reservoir pressure now passes to the under side of the feed-valve 21, which latter is held to its seat by "feed-valve spring" 20, having a resistance of about twenty pounds.

When this additional pressure is accumulated in the main reservoir, "feed-valve" 21 is forced open, the air passing thence through "feed-port" *f'* to port 1 and the train-pipe, while train-pipe pressure is maintained in chamber *D* through port 1, cavity *c* and "equalizing-port" *g*, thus equalizing the pressure above and below piston 17, the stem of which, forming a valve, is seated in the position shown in "bottom-cap" 5, and permits the escape of air from the train-pipe to the atmosphere through ports *m* and *n* when raised from its seat.

When applying brakes for ordinary or station stops, move handle 8 to "on lap" position. This blanks all ports in the rotary-valve and seat. Then moving the valve-handle to the position "application of brakes, service-stop," the small exhaust-cavity *p* in the lower surface of the rotary valve 13 establishes communication between the two "preliminary exhaust-ports" *e* and *h*, the latter leading to the atmosphere, and after discharging about 8 pounds of pressure as shown by the gauge, restore the handle to "on lap" position.

This preliminary discharge of air from the chamber *D* will cause the piston 17 and its stem to rise, which operation is followed by a discharge of air from the train-pipe to the atmosphere through ports *m* and *n*, applying the brakes gently.

This discharge of air from the train-pipe *continues after the valve-handle is carried to "on lap" position* (gradually equalizing train-pipe pressure), *and until the train-pipe pressure has been reduced slightly lower than that yet remaining in the chamber above the piston*, when the latter is forced downward and its stem to its seat, closing the outlet *n*, and preventing the further escape of air, until the operation is repeated, which may be necessary to apply the brakes with the desired degree of force.

To throw off brakes, push handle 8 to "position for releasing brakes," causing the excess of air-pressure in the main reservoir to be discharged into the train-pipe, insuring their prompt and certain release.

For an "emergency" application of brakes, push the handle to the extreme right, to position "application of brake emergency-stop." This operation establishes direct communication between the train-pipe and the atmosphere, through the "direct application and supply-port" 1, cavity *c*, and the "direct application and exhaust-port" *k*, applying the brakes with their full force instantly.

When handling trains on down-grades, let the brake-valve handle remain in full release position, except when applying brakes, which will insure the full and prompt recharging of auxiliary reservoirs under cars.

If the engineer's brake-valve bracket is to be located against the boiler-head, it must be made of sufficient length to prevent injury to the valve-gaskets by heat.

After being placed in position on the engine, and before using, it is a good practice to remove valve 13, and wipe its face and seat quite clean of any grit that may have lodged thereon in transit; rub a *little* tallow on the surfaces, and replace.

Care in this respect will prevent the valve and seat from cutting. Any leakage between the valve and seat may result in establishing communication between the several passages or ports therein, and thus prevent the very desirable results for which the valve was particularly designed. When this occurs it is necessary to regrind valve 13, which may be done by carefully facing and scraping the surfaces to a good seat, after which use a *small* quantity of fine-ground glass, sieved through cloth of close texture, and a little oil. Usually the valve only requires facing.

It is of the utmost importance that *direct communication be made from the engineer's brake-valve to the main reservoir*, instead of connecting to the discharge-pipe leading from air-pump to main reservoir.

The latter practice is very undesirable, as a great deal of moisture and oil is discharged into the train-brake system which would otherwise be deposited in the main reservoir from which it can be readily drained.

A one-inch stop-cock should be placed in the train-pipe, a short distance below the engineer's brake-valve, within convenient reach of the engineer, and should be closed upon all but the leading engine of the train, where two or more engines are coupled in the same train, in order that the head engine may operate the train-brakes.

It is important that the pipe-connections to the brake-valve be perfectly air-tight, and that the valve should occasionally be cleaned. The feed-valve 21 can be readily removed for cleaning by the engineer, by placing the valve-handle in "emergency" application position, which will retain the air in the main reservoir, then unscrewing the cap-nut 19.

This should be done occasionally, as any derangement by which its functions of maintaining an excess pressure in the main reservoir is usually found to be due to the presence of dirt or gum from the use of too much oil or lubricant of an inferior quality. The piston should also be removed for cleaning, at intervals, as the presence of gum interferes with its free movement.

THE PUMP-GOVERNOR.

The construction of the pump-governor is illustrated in cross-section in Fig. 121. Its purpose is to automatically shut off the supply of steam to the pump when the air-pressure in the train-pipe and auxiliary reservoirs has reached the limit allowable, say 70 pounds, this pressure forming the basis upon which the maximum power of the brake-gear used on cars and engines is designed, thus avoiding excessive air-pressure, which, used indiscreetly, will result in sliding wheels. With a judicious use of the brake and maintenance of pressure to the maximum allowable, sliding of wheels may be avoided.

The simplicity of construction of the governor is such that the following description of its mechanism will make it readily understood:

By reference to Fig. 121 it will be seen that suitable provisions are made for attaching the end *Y* of the governor directly to the steam-pipe union connection of the air-pump, the opposite end *X* being piped to the source of steam-supply. Another pipe connection, with union swivel 21 at *W*, is also made and extended to the fitting 30, Fig. 117, in the engineer's brake-valve. This fitting, it will be observed, is tapped into a port of the brake-valve, *which is always in direct communication with the train-pipe, the pressure to be governed*, and which, acting upon the under side of the flexible diaphragm 19, forces it upward against the resistance of the regulating spring 18, when the desired train-pipe pressure has been reached, lifting valve

PUMP GOVERNOR.

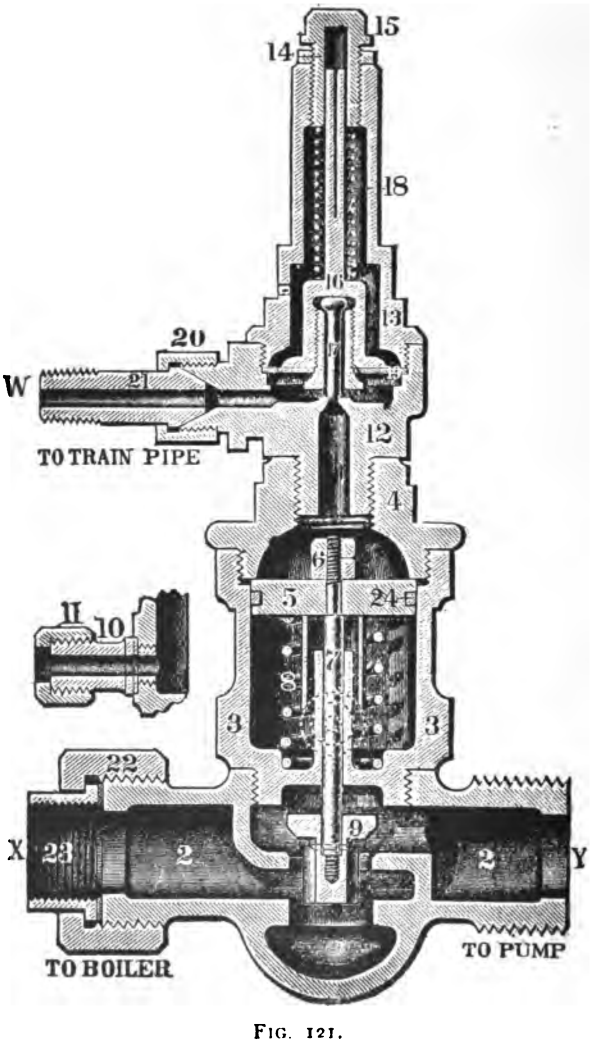


FIG. 121.

17 from its seat, admitting air-pressure on top of piston 5, forcing steam-valve 9, with which it is connected by stem 7, to its seat, shutting off the supply of steam.

A reduction of air-pressure in the train-pipe by applying brakes causes a reverse movement of the governor, valve 17 closing, and the pressure contained in the chamber above piston 5 leaking away past its edges to the atmosphere through the exhaust connection 10 in cylinder 3.

Spring 8 then forces the piston upward, opening steam-valve 9, and permitting steam to again pass to the pump. Any necessary adjustment of the regular spring 18 is readily made by means of nuts 14 and 15.

A good quality of lubricant should be continuously fed to the steam-cylinder of the pump while in operation. A small quantity of 32° gravity West Virginia well-oil should be used at intervals in the air-cylinder, it being particularly desirable to use a quality of oil which will cause the least gummy deposit in the air-passages, reducing their dimensions and preventing the free discharge of air in the main reservoir. Tallow, lard-oil, or kerosene must not be used in the air-cylinder.

Attention is drawn particularly to the description of the brake-valve contained in this work, and the fullest advantages should be taken of the opportunity it affords for the correct operation of the brakes.

Care should be taken to discharge six or eight pounds of air by the gauge in the first instance in applying brakes for ordinary stoppages, which will cause the pistons in the brake-cylinders to move outward sufficiently to close the leakage-groove, forcing the brake-shoes lightly against the wheels. Further reductions of pressure may thereafter be made to suit circumstances.

The brakes are fully applied when the pressure in the train-pipe, and as shown on the gauge, has been reduced 20 pounds.

Any further reduction is a waste of air. It is of great importance that the engineer should remember that the gradual application of the brakes is caused by a gentle discharge of air-pressure from the train-pipe to the atmosphere, and that a rapid discharge causes the quick action of the brakes to ensue.

It is therefore essential that he exercise some degree of care and moderation in applying brakes, taking advantage of the emergency action of the brakes only when absolutely necessary to avoid accidents.

Engineers, upon finding that the brakes have been applied by the trainmen or automatically, must at once aid in stopping the train by using the brake-valve as in making ordinary stoppages, which will prevent the loss of pressure from the main reservoir, and enable the prompt release of brakes when necessary.

It is important that the main reservoir be drained of water at regular intervals, especially in moist climates and seasons. As much of this accumulation is condensed from the steam-cylinder and passes into the air-cylinder through imperfectly-packed piston stuffing-boxes, care should be taken to avoid this.

The shoes of driving-wheel brakes should be so adjusted, by means of the cam-screws, that the pistons move from 3 to 5 inches when the brakes are applied.

If cars having different air-pressures be coupled together, the brakes will apply themselves to those having the highest pressures in the auxiliary reservoirs.

To insure the certain release of all the brakes in the train, and also that the reservoirs may be quickly charged, the engineer must carry the maximum pressure in the main reservoir before connecting to a train.

On long down-grades it is important to be able to control the speed of the train, and at the same time to maintain a good working air-pressure.

This is readily accomplished on ordinary gradients, where the pressure-retaining valve is not necessary, by running the pump at a good speed, so that a comparatively high pressure will have been accumulated in the main reservoir while the brakes are on, and which when released enables the auxiliary reservoirs to be speedily recharged before the speed has increased to any considerable extent.

It should be sought to control the train on any grade by the use of the smallest quantity of air possible and the fewest number of applications of the brakes.

QUESTIONS ON 8″ AIR-PUMP, FIG. 111.

What is the purpose of the third or top piston-head?

The third or top piston-head helps to reverse the valve-motion and to force the main piston-head or valves downward so as to open the bottom port.

Which piston-head or valve in main valve-chamber has the larger diameter?

The top one.

Which is the reversing-valve, and where is it situated?

The reversing-valve is the top head of steam-cylinder.

What is the shape of this valve?

It is a small slide-valve.

How is it moved?

By a valve-rod which extends down into the main piston-rod, this rod being hollow. The reverse-valve rod has a shoulder on its end, which comes in contact with a plate on main steam piston-head, which pulls the valve down, and the reverse-valve rod is pushed up by the main piston-rod, by the end of reverse-valve abutting against the main piston-rod.

How does the slide-valve reverse the movement of pump piston-heads?

By letting steam in on top of the third or top piston-head of valve-motion, also by exhausting from the same. Suitable ports are provided for the same.

How is the air-pressure accumulated

By the air-pump.

What are the principal parts of a pump?

The steam-cylinder and the air-cylinder.

Which is the air-cylinder in the Westinghouse Pump?

The bottom cylinder.

How is the air drawn into the air-cylinder?

A piston-head works in the air-cylinder which is fastened to the piston-rod, extending to the steam-cylinder and also attached to the steam piston-head. When the piston goes up and down in cylinder it causes a displacement in the air-cylinder, into which the atmosphere rushes, filling up the air-cylinder.

How is the inlet and outlet of air controlled?

By suitable valves called receiving and discharging valves. (Fig. 111.)

How many small piston-heads are in the steam-valve motion?

Three. Two on the main-valve stem, in the steam-chamber, and the third one is in the chamber above the main chamber. This head has a stem extending through the chamber resting on top of the top piston-head in main steam-chamber.

Why are the piston-heads in main valve-chamber of different diameters?

In order that the piston-heads which serve as valves will move in the direction of the larger head, the steam entering between the heads.

In what do these valves work?

In bushings forced into the chambers.

Why is this done?

In order that the bushing can be renewed without dispensing with the pump when they become much worn.

Describe the movement of the pump in Fig. 111.

As shown in the figure, the steam is entering the lower ports, driving the piston-head upward. The exhaust is passing out the upper ports, into the exhaust-passages around the pump, to exhaust-pipe. The third or top piston-head has steam on the upper side, which has forced it down with the main valves. When the main steam piston-head is near the end of its upward travel, it will strike the reverse-valve rod, and that will move the valve over the ports leading to top piston-head and exhaust the steam from it, when the main valves will move upward and open the upper ports to drive piston-head downward again.

How is the piston-rod packed in main pump?

By a composition packing.

What is the effect on a pump when this packing leaks badly?

It makes one end of the pump useless, because the air will escape into the atmosphere instead of being forced into the reservoir.

When a pump-piston rod is packed, what is necessary to keep it from burning out?

It should be well lubricated, and kept tight to piston-rod, for if it leaks badly around the piston-rod it will burn the packing out, for the air under a pressure causes a great friction when escaping, which will set the packing on fire. Air under pressure gives off its latent heat.

What are the other causes which make an air-pump run hot?

Running the pump without lubrication in either air or steam end, which causes the rings to cut; too high air-pressure in reservoir, rapid running of pump, and valves gummed up in air-cylinder, which causes an excessive friction.

What causes a pump to stop working?

A reversing-valve rod broken; plate on piston-head loose; piston valve-rings broken or leaking; steam passage to reversing-valve stopped; bottom or air-cylinder piston-head broken off from piston-rod.

THE NINE-AND-ONE-HALF-INCH IMPROVED WESTINGHOUSE AIR-PUMP.

It will be seen from the cuts of the Nine-and-one-half-inch Pump, here presented, that the valve-motion is entirely in the top head of the steam-cylinder, while in the ordinary eight-inch pump a portion of it is located in the steam-cylinder proper. In repairing the valve-motion it has heretofore been necessary to get at both the steam-cylinder and the top head, but in the new pump, as all of the moving parts are concentrated in the top head alone, its repair is greatly facilitated. A square-top head can be carried on the locomotive and readily substituted for a defective one during a run should there be any necessity for an operation of this kind. The number of parts of the valve-motion has been considerably reduced, and they are less delicate constructively than those used in our standard eight-inch pump.

The principal improvement in the air-cylinder is in the arrangement of the air-valves. Each one is contained in a separate case, and all are made of the same size. It is therefore necessary to carry but one kind in stock for the complete repair of this portion of the air-pump. By this general arrangement the lift of each valve is controlled by an ample contact surface with the cap of the valve-case, or with the case itself, and a change in the lift of one valve has no effect upon any of the others. An air-strainer is provided for the inlet opening, which is on the left side of the pump, and so located as to offer the least chance for taking dust and cinders in the air-cylinder. In all matters of detail, such as the size of the bolts and proportioning of parts, great care has been exercised to make them ample for their intended use. We have carefully examined into

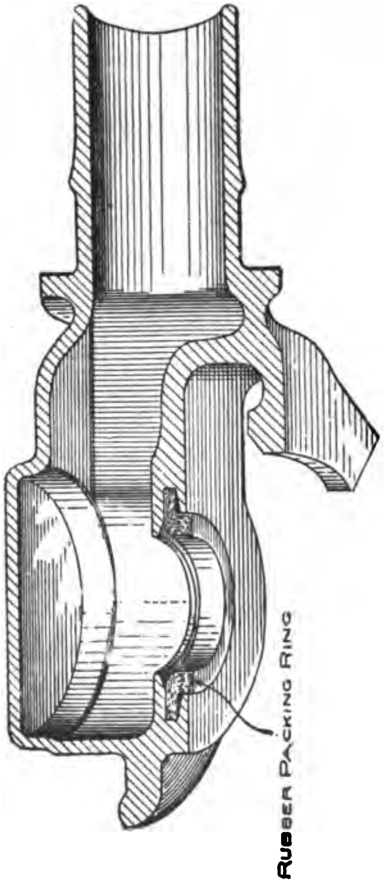
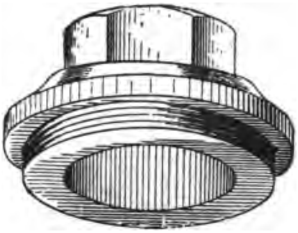


Fig. 122.—New Style Hose Coupling.

the nature of the repairs that we have heretofore furnished on our standard pump, and have been guided by our observations on this point in the character of some of the changes made in detail construction. This pump, as compared with our standard eight-inch pump, has an increased capacity of 65 per cent, and to compress a given amount of air at 90 pounds requires 20 per cent less of steam.

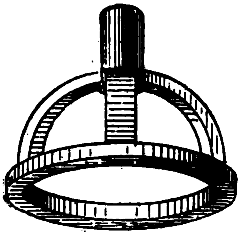
Description.—As will be seen by reference to Figs. 127 and 128, the valve-motion of the pump consists of two pistons 77 and 79 of unequal diameter, mounted on rod 76, while a slide-valve 83, of the D type, held in position between them, provides for the distribution of steam to the upper and lower sides of main steam-piston 65, as required. Steam enters the pump at *X*, where a suitable stud and nut admit of the direct attachment of the pump-governor, and by means of passages *a* and a^1, and port a^2, is admitted to slide-valve chamber *A*, between the two pistons 77 and 79, where, by reason of the greater area of the former, tends to force it to the right to the position in which the valve is shown in



Coupling Cap.

FIG. 123.

OLD STYLE.



Packing Ring Washer

FIG. 124.

Fig. 127, thus admitting steam to the under side of main piston 65 through port *b* and passages b^1 and b^2, forcing it upward, while the steam previously used on the opposite side in forcing the main piston downward is exhausted to the atmosphere through passage *c*, port c^1, cavity *B* of the slide-valve 83, port *d*, and passage d^1 and d^2 at the connection *Y*, from whence it is conveyed by suitable pipe to the smoke-box of the locomotive.

In Fig. 127*a* is illustrated an outside view of main-valve bushing 75, showing the several ports and steam-passages therein, of which port *t* communicates between chamber *E* in the main-valve head 85 and exhaust-passage f^1, and hence is in constant communication with the outside atmosphere, relieving the pressure on the surface of main-valve piston 79 exposed to chamber *E*. A reversing-valve 72 operates in chamber *C* in the centre of the steam-cylinder head, steam being supplied thereto from slide-valve chamber *A* through ports *e* and e^1, and which is given motion through the medium of a rod 71 extending into the space *k* of the hollow main-piston rod. The duty of this valve is that of admitting steam to and exhausting it from space *D* between main-

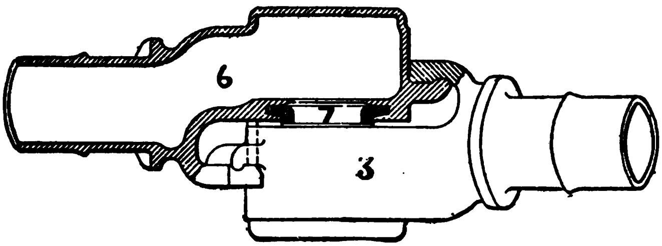


FIG. 125.

valve piston 77 and the head 84, and is shown in Fig. 127 in position to exhaust the steam previously used, from the space *D* through port *h* (Fig. 128), port h^1, reversing-valve cavity *H*, and ports *f* and f^1 to the main exhaust-ports *d* and d^1 and d^2.

It will at once be apparent, having described how the surface of main-valve pistons 77 and 79 exposed in chambers *D*, and *E*, respectively, being free from pressure other than the outside atmosphere, that the steam on the opposite side in chamber *A* is exerting a force in both directions, but the total force toward the right is greater by the sum of the steam-pressure in chamber *A* multiplied into the difference between their areas. This effect, however, is reversed when the main piston, approaching the upward termination of its stroke, strikes the shoulder *j* of the reversing-valve rod 71, forcing the rod and its valve 72 upward, causing the admission of steam from chamber *C* to chamber *D* through

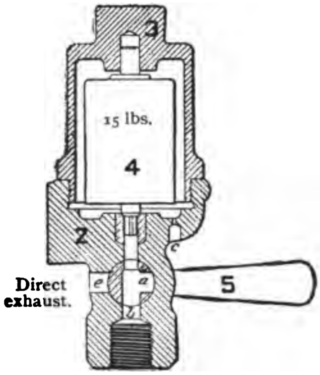


FIG. 126.—RETAINING-VALVE (set).

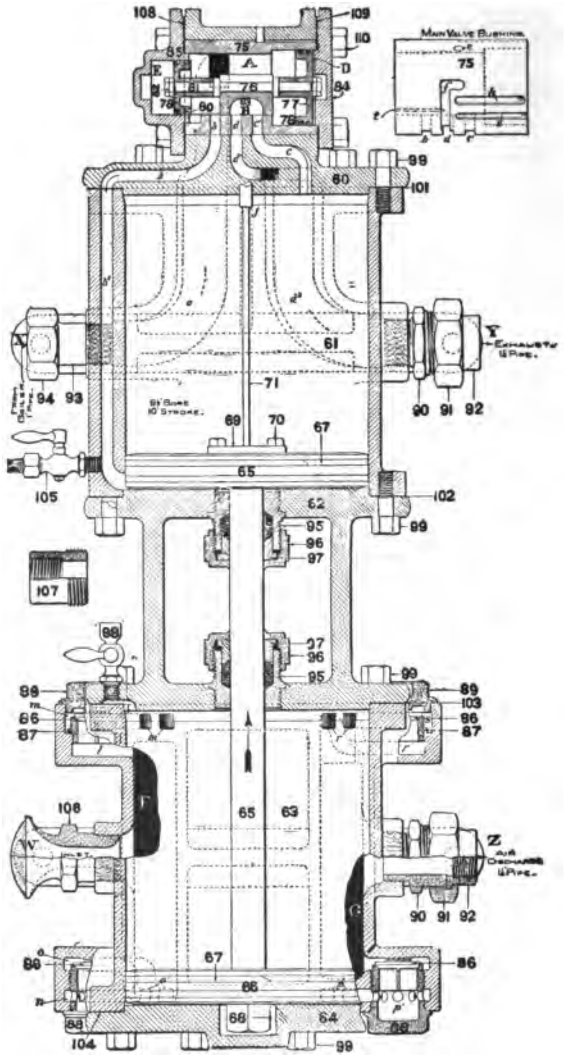


FIG. 127a.

FIG. 127.

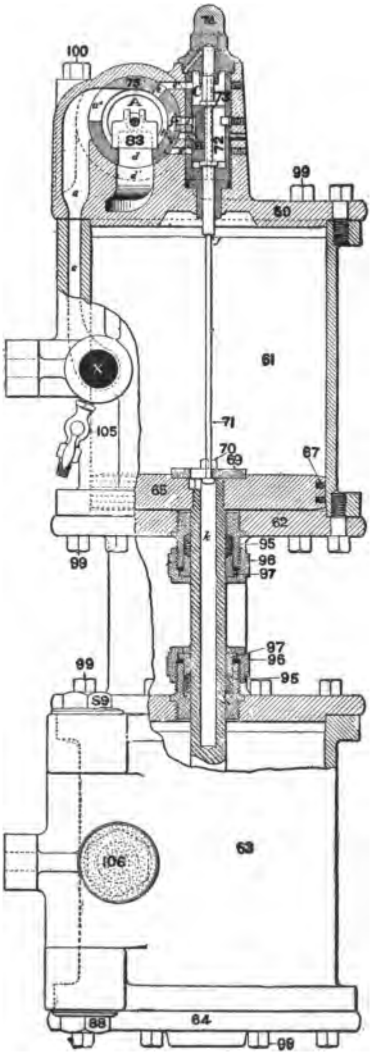

a'
A
d
d'
a
e
X
k

FIG 128.

ports g and g^1 (Fig. 128), thus balancing the pressure on both sides of main-valve piston 77, when the steam in chamber *A*, acting upon the effective area presented to it of main-valve piston 79, forces it to the left, and live steam is again admitted to the upper side of main steam-piston 65, exhausting from the opposite side, and forcing it downward until at the lower termination of its stroke the button-head on the lower end of the reversing-valve stem 71 comes in contact with reversing-valve plate 69, again moving reversing-valve 72 to the position shown in Fig. 128, completing the cycle of its movement.

Coincident with the reciprocal movements of the main steam and air pistons, air from the outside atmosphere is drawn alternately into the respective ends of the air-cylinder 63, through the screened inlet 106 at *W*, chamber *F*, and receiving-valves 86 to the left, Fig. 127, and from thence discharged under pressure through discharge-valves 86 to the right, Fig. 127, to chamber *G* and the main reservoir, to which the pump should be connected by one and one-fourth inch pipe at *Z*. The lift of receiving and discharge valves 86 should be three thirty-seconds of an inch.

THE IMPROVED ENGINEER'S BRAKE AND EQUALIZING-DISCHARGE VALVE, WITH FEED-VALVE ATTACHMENT.

In the construction of the new engineer's brake and Equalizing-discharge Valve, with feed-valve attachment, two important improvements have been made, one operative and the other constructive.

In operation, this valve is so arranged that when the handle is in "running position" the pressure in the train-pipe is automatically cut off when it reaches 70 pounds, regardless of any higher pressure that may be in the main reservoir, and any loss in the train-pipe, due to leakage, is automatically supplied. The amount of excess pressure to be carried in the main reservoir for the purpose of recharging and releasing promptly is regulated by the pump-governor, which is adjusted to stop the pump when the maximum pressure has been reached therein. The construction of the previous engineer's brake and equalizing-discharge valve (Fig. 118) is such that when the handle is in "running position" the regulation of pressure in the train-pipe is dependent upon the operation of the pump-governor, and the amount of excess pressure in the main reservoir is controlled by what is called an excess-pressure valve, but which is more accurately described as a valve for creating a predetermined difference of pressure between the main reservoir and train-pipe. This valve is usually so adjusted that when a pressure in the main reservoir of 20 pounds in excess of that in the train-pipe is reached it will open and supply air to the train-pipe, but no communication between the main reservoir and the train-pipe exists until this difference in pressure is secured. It is therefore evident that when the handle of the engineer's valve is returned to "running position," after having been placed in full release position (in which latter position the pressure in the main reservoir and train-pipe equalizes), it is necessary to accumulate an excess pressure of 20 pounds in the main reservoir before air can pass the excess pressure-valve to supply any deficiency in the train-pipe, due to leakage or the charging of auxiliary reservoirs.

From the above explanation it will be seen that the differences in operation between these two valves are:

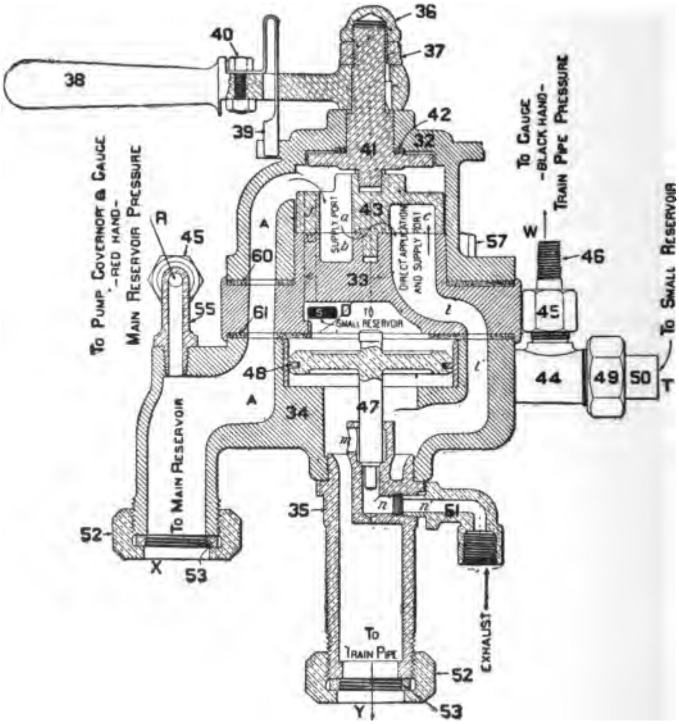


Fig. 129.

First. With the new valve air is automatically supplied to the train-pipe until 70 pounds pressure is reached, if there is a pressure of 70 pounds or greater in the main reservoir. Train-pipe pressure in the previous valve is regulated by the pump-governor. It therefore dispense with the pump-governor for the purpose of controlling train-pipe pressure with the new valve.

Second. With the new valve, when the handle is in "running position," provision is made for constantly supplying the train-pipe with air for any loss of pressure due to leakage at the pipe-joints, or from other sources. With the old valve it is necessary to have an excess pressure in the main reservoir of not less than 20 pounds before air can be supplied to the train-pipe for the purpose of compensating for leakages when the handle of the valve is in "running position."

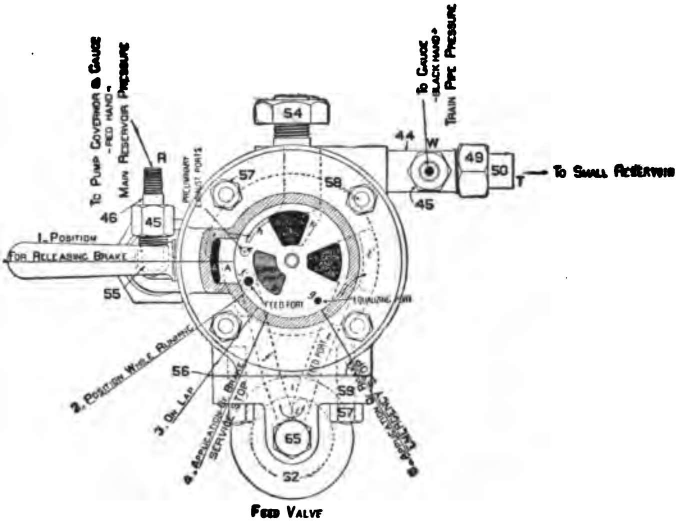


FIG. 130.

Third. With the new valve, the only duty of the pump-governor is to regulate the degree of excess pressure in the main reservoir, and as this may, and often should be, varied within considerable limits, the sensitive and delicate operation of the pump-governor is not essential. A desired variation of excess pressure is readily had by an adjustment of the tension-nut of the governor-spring. With the old valve the governor regulates train-pipe pressure, and accurate adjustment is imperative to accomplish effective braking. Excess pressure is regulated by the tension of a spring controlling an excess-pressure valve, and cannot be changed except by the substitution of different springs and a readjustment of the pump-governor.

Constructively, the principal feature of the new valve is an opportunity for the removal of all of the operative portions for inspection or repair, without breaking or disturbing any of the pipe connections. The main rotary valve and its seat are made of different metals which reduces the effect of wear to a minimum.

Description.—Pipe connections must be made to the main reservoir at *X*, to the train-pipe at *Y*, to the equalizing-reservoir at *T*, and to the duplex gauge at *R* and *W*, respectively for main reservoir and train-pipe pressures. The gauge-pipe from *R* should be extended to the air-pump governor, which latter device should be set to stop the pump at 85 to 100 pounds pressure, thus providing for an excess pressure of 15 to 30 pounds above standard train-pipe pressure of 70 pounds per square inch. The amount of excess pressure required depends upon the length of trains and character of the road—whether level or with long and severe gradients. Ordinarily 15 to 20 pounds excess pressure is ample for the safe operation of brakes on the ordinary railway.

While the handle is in position 1, "for releasing brakes,"* air from the main reservoir enters the brake-valve at *X*, passing through ports *A*, *A*, thence through port *a* in the rotary valve 43 to the port *b* in its seat 33, thence upward into cavity *c* of the rotary valve, and finally to ports *l* and l^1 and the train-pipe at *Y*. Port *j* in the rotary valve and *e* in its seat are in register in this position, and admit air to chamber *D* above equalizing-piston 47, and passing thence through ports *s* and *s*, charges the small equalizing-reservoir connected at *T*. The train-pipe and auxiliary reservoirs of the brake apparatus being charged, the handle 38 of the brake-valve being moved to 2, "position while running," ports *a* and *b*, and *j* and *e*, are no longer in communication, and air then reaches the train-pipe through port *j* in the rotary valve 43, and ports *f* and f^1 in its seat 33, passing thence through feed valve 63 to port *i*, ports *l* and l^1 to the train-pipe, and continues to flow thereto until the pressure in chamber *B* upon diagram 72 exceeds the resistance of spring 68, and, forcing the diaphragm and its attachments downward, feed-valve 63 closes until such time as by reason of any leaks in the train-pipe the pressure therein has been reduced below 70 pounds, when the valve 63 is again automatically pushed open by the diaphragm rising, replenishing train-pipe pressure. Equalizing-port *g* is now in communication with chamber *D*, maintaining train-pipe pressure therein, through ports l^1, *l*, and cavity *C* in the rotary-valve 43. The necessary adjustment of spring 68 is readily accomplished by means of adjusting-nut 70, to which access is had by the removal of cap check-nut 71.

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* See Figs. 130 and 131.

To apply the brakes the handle 38 of the valve is moved to position 4, "application of brake—service stop," bringing into conjunction port *p* (a groove in the under side of rotary valve 43) and ports *e* and *h* (the latter also a groove) in its seat, causing air to any desired extent to be discharged to the atmosphere from the chamber *D* above piston 47 and the equalizing-reservoir, through the large direct-application and exhaust port *k*, thus reducing the pressure above piston 47 and causing that in the train-pipe below to force it upward from its seat, permitting air to flow from the train-pipe through ports *m*, *n*, and *n*' to the atmosphere through exhaust-connection 51. The desired reduction of pressure in chamber *D* being made, the handle of the valve is moved backward to position 3, "on lap." It must be borne in mind that after the handle of the valve has been moved to lap position air will continue to flow from exhaust-fitting 51 until the pressure in the train-pipe has been reduced to an amount approximating that in chamber *D*. Ordinarily, a reduction of 6 to 8 pounds pressure by the gauge from chamber *D* is sufficient to apply the brakes in the first instance slightly, and will cause a corresponding reduction of train-pipe pressure by the rising of piston 47, which latter, when such reduction has taken place, is automatically forced to its seat by the preponderance of pressure on its upper surface from air remaining in chamber *D*.

The release of the brakes is effected by moving the valve-handle 38 to "position for releasing brake," causing air from the main reservoir to again freely flow to the train-pipe, forcing the triple-valve pistons to release position, and exhausting air used in applying

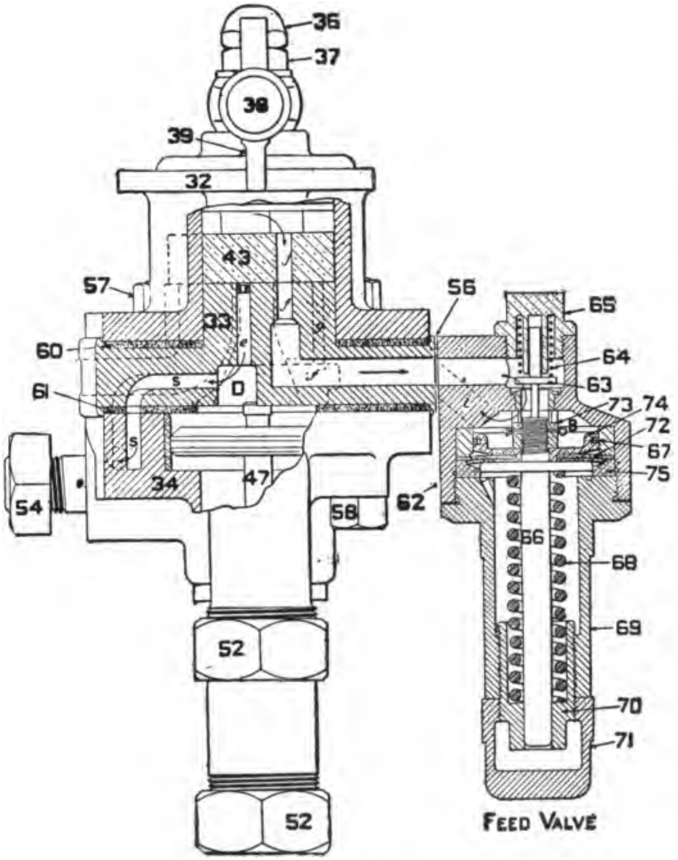

Fig. 131.

the brakes and recharging the auxiliary reservoirs. While the handle of the valve is in this position a "warning-port" of quite small size causes air from the main reservoir to be discharged to the atmosphere with considerable noise, attracting the engineer's attention to his neglect to move the valve-handle to "running position." The engineer must move the handle of the brake-valve from position 1 to position 2 prior to the accumulation of the maximum pressure of 70 pounds allowed in the train-pipe, so that the feed-valve attachment may properly perform its functions of governing train-pipe pressure; otherwise the privileged pressure in the train-pipe may be considerably augmented, which must be carefully avoided. With trains of ordinary length it will be found that the brakes can be readily released and the auxiliary reservoirs promptly recharged by simply returning the handle to "running position" (2).

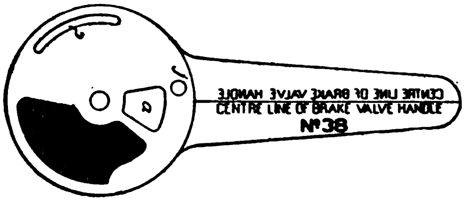

FIG. 132.

For an emergency application the handle 38 of the brake-valve is moved to the extreme right, position 5, "application of brake—emergency-stop," when "direct-application and exhaust port" *k* and "direct-application and supply port" *l* are brought into conjunction by means of a large cavity *c* in the under surface of the rotary valve 43, thus admitting of the discharge from the train-pipe of a large volume of air to the atmosphere, causing the quick action of the brakes. Such action, however, should be employed only in an emergency. A reduction of 20 to 25 pounds pressure in the train-pipe at the brake-valve is sufficient to apply the brakes to their maximum, and any further reduction of pressure is consequently a waste of air. It will be noted that this valve is manipulated in the same manner as the preceding pattern, and that additional instructions in this respect to engineers are unnecessary.

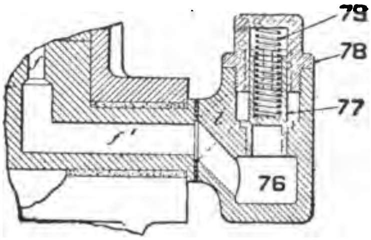

FIG. 133.

An excess-pressure-valve arrangement, illustrated in Fig. 133, may be substituted for the feed-valve if desired, restoring that feature substantially as arranged in the Fig. 118 form of engineer's brake-valve, and in that event the pump-governor should be similarly connected to the train-pipe, and for which purpose suitable provision is made when new brake-valves are ordered accordingly.

By preparing a diagram of tracing-cloth or gelatine similar to Fig. 132, and placing it in a reversed position on Fig. 130, where it may be rotated on a centre, the foregoing explanation may be followed with ease by those interested.

In erecting the valve on a locomotive it should be placed at a reasonable distance from the boiler, in order to prevent its gaskets drying out and shrinking, and care taken to make the pipe-joints absolutely tight. After it has been erected, and all of the connecting pipes have been carefully blown out, it is advised that rotary valve 43 be removed and a little tallow be rubbed on its surface and its seat, then replaced. The valve should occasionally be removed and cleansed of the gummy deposits which will be found thereon, the extent of which will be determined by the amount of oil used in the air-cylinder of the pump.

THE THREE-FOURTHS-INCH IMPROVED PUMP-GOVERNOR.

The improvements in the new Three-fourths-inch Pump-governor illustrated have been dictated largely by past experience, and it is believed the source of complaints in earlier constructions have been entirely eliminated.

Three notable changes have been made:

First. The adjusting-spring has been made more substantial and resilient, and consequently more sensitive to variations in pressure.

Second. The form of steam-valve has been modified to lessen the abrading effect of steam and the obstruction of its passage to the pump.

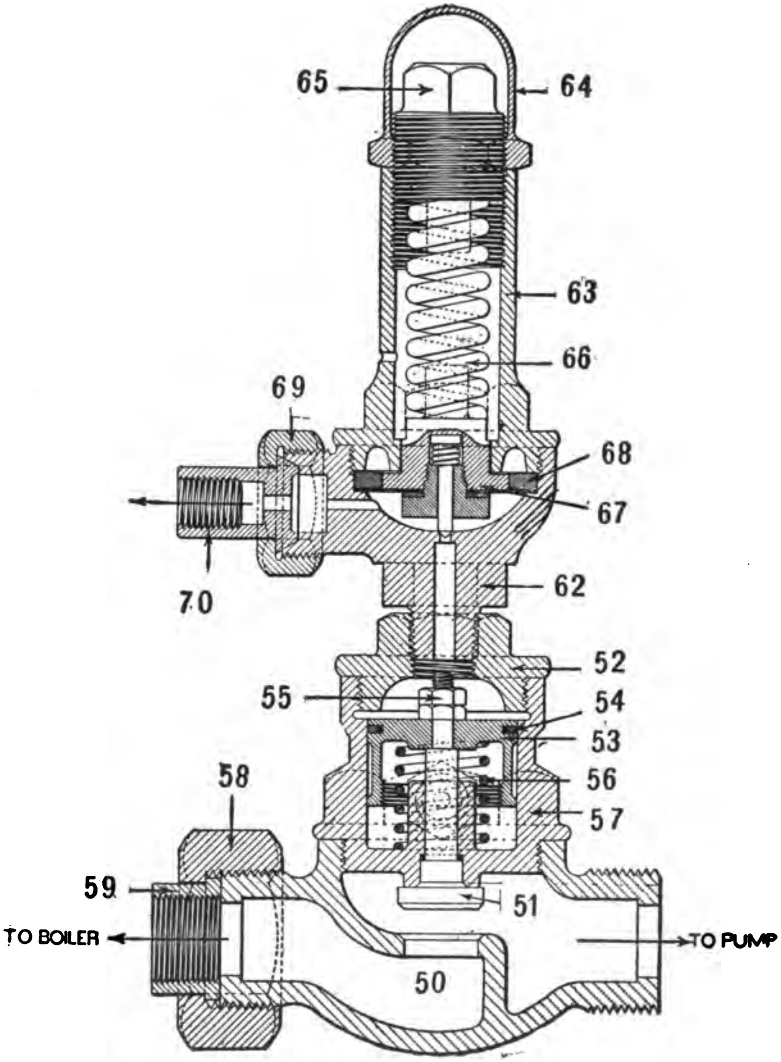
TO BOILER
TO PUMP

FIG. 134.

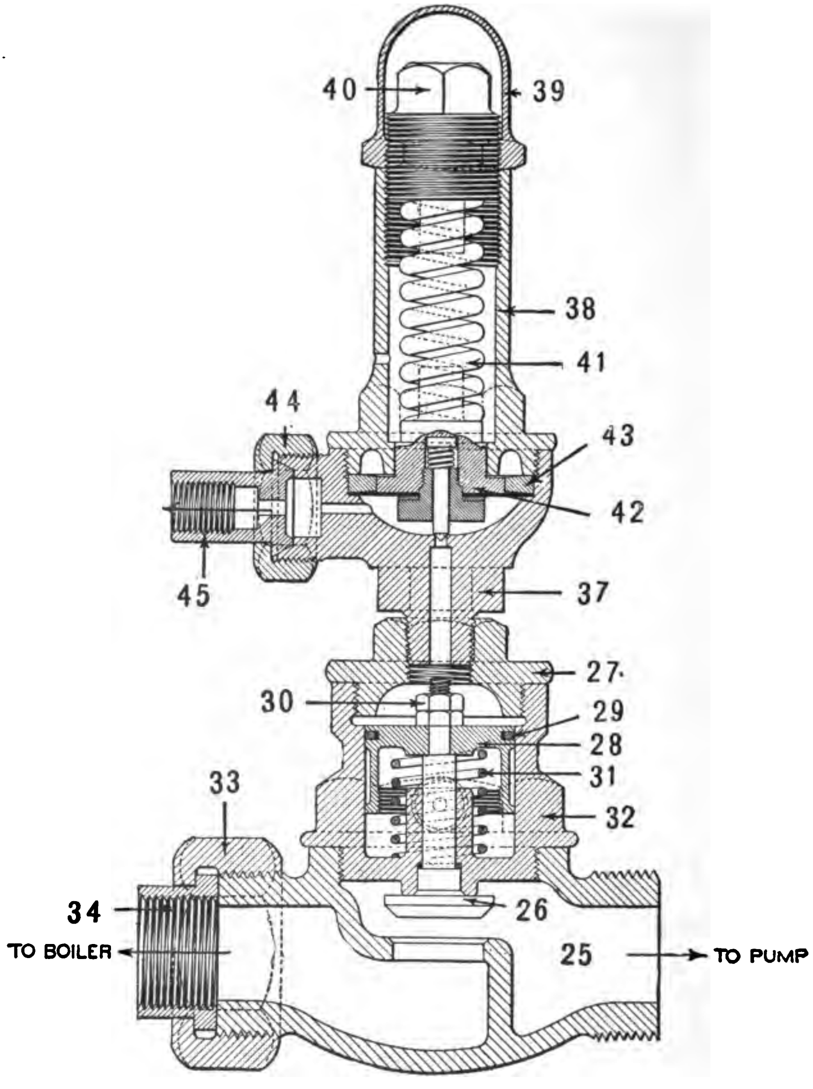

FIG. 135. *

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* 1-INCH GOVERNOR.

Third. The diaphragm is composed of two thin sheets of metal, making it more sensitive to variations of pressure than with the single plate formerly used, and is supported by metallic walls in such a manner as to make its distortion under extreme pressures practically impossible.

Description.—Air under pressure entering the governor at fitting 70 acts upon the under side of the diaphragm 67 and forces the latter upward when the maximum pressure for which the governor has been adjusted has been reached, lifting the small conical-shaped valve attached from its seat, and admitting air above piston 53, forcing the latter and its steam-valve downward, shutting off steam to the pump. By relieving the pressure under the diaphragm, in operating the brakes, the conical valve referred to is again seated, and the pressure in the space above piston 53 leaking away to the atmosphere past the piston and through fittings 60 and 61, steam-pressure under the valve 51, aided by spring 56, forces the steam-valve open to its normal position shown in the illustration, again admitting steam to the pump.

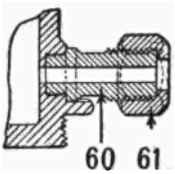

FIG. 136.

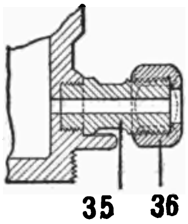

FIG. 137.

When the pump-governor is used in connection with an engineer's brake-valve fitted with a feed-valve, the union swivel 70 must be connected by suitable pipe to the main reservoir, and likewise must be connected to the train-pipe when used in connection with an engineer's brake-valve having an excess-pressure valve in its construction. In either case suitable attachments are provided on the brake-valve.

If the governor is attached to the train-pipe, it should be adjusted to stop the pump at 70 pounds pressure per square inch; if coupled to the main reservoir, it should be adjusted to stop the pump at 85 to 100 pounds pressure, as the amount of excess pressure required is dependent upon the length of trains and the character of the road—whether level, or with long and heavy gradients. Ordinarily 15 to 20 pounds excess pressure is ample for the safe operation of brakes on the ordinary railway.

Required adjustments of the governor for desired pressures at which it will stop the pump are readily made by means of regulating-nut 65, to which access is had by the removal of cap-nut 64.

THE MASON AIR-BRAKE PUMP-REGULATOR.

This regulator is designed to automatically control the air-pressure in the brake system for operating the brakes on railroad cars. It is placed in the steam-supply pipe leading to the air-pump, and regulates the amount of steam passing to pump, and allowing the pump to run just sufficiently to maintain the desired air-pressure in the train service-pipe.

*Description.**—The principle on which the Mason Air-brake Regulator works is that of an auxiliary-valve 8, controlled by the air-pressure from the train service-pipe, through the medium of a metal diaphragm 24, and admits steam from the initial side of regulators through a port to operate a piston 19, which in turn opens the main-valve 21, and admits steam to the pump. By referring to the sectional view, it will be seen that the steam enters the regulator at the side marked "steam from boiler," a small portion of it passing up through the passage *XX* to the auxiliary-valve 8. This valve

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* Figs. 138 and 139.

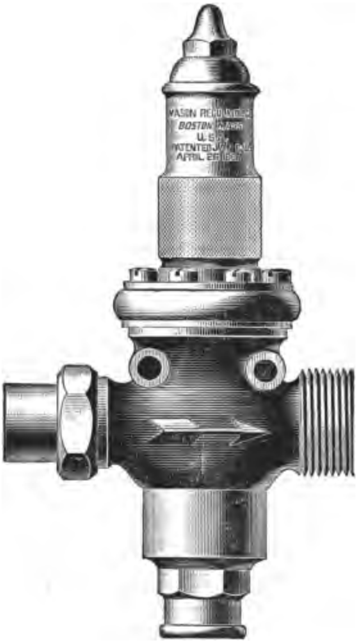

FIG. 138.—GENERAL VIEW OF MASON PUMP-REGULATOR.

8 is forced open by the compression of the large spiral spring 5 acting on the cricket through the diaphragm. This cricket 6 has three studs projecting down from the rim, which pass through three loosely fitting holes in the bonnet, the lower ends resting on a button 11 which sits on the diaphragm, so that in opening the valve 8 the diaphragm is also forced down. As soon as the valve 8 is opened, steam passes through and into port *Z*, down under piston 19. By raising this piston 19 the main-valve 21 is opened against the initial pressure, since the area of valve 21 is only one half of that of piston 19. Steam is thus admitted to the pump. A connection with the main air-pipe is made as indicated; and by a passage air enters the chamber below the diaphragm, which carries the cricket 8, as before stated. When the pressure in the air-pipe 16 and chamber *O* has risen to the required point, which is determined by the tension of the spring 5, the diaphragm is forced upward by the air-pressure in the chamber, carrying with it the cricket 6, and allowing valve 8 to close, shuttin goff the steam from piston 19. The main-valve 21 is now forced to its seat by the initial pressure, shutting off steam from the pump and pushing the piston 19 down to the bottom of its stroke. The steam beneath this piston exhausts freely around it — the piston being fitted loosely for this purpose—and passes off into the pump. The leakage past the auxiliary-valve 8 passes up under the cricket and out into the spring-case, where it makes its escape down through the cricket-holes to the upper side of the diaphragm and into the drip. It will be seen from this that when the pressure in the

brake-pipe has reached a predetermined point the pump will be automatically stopped; and when the

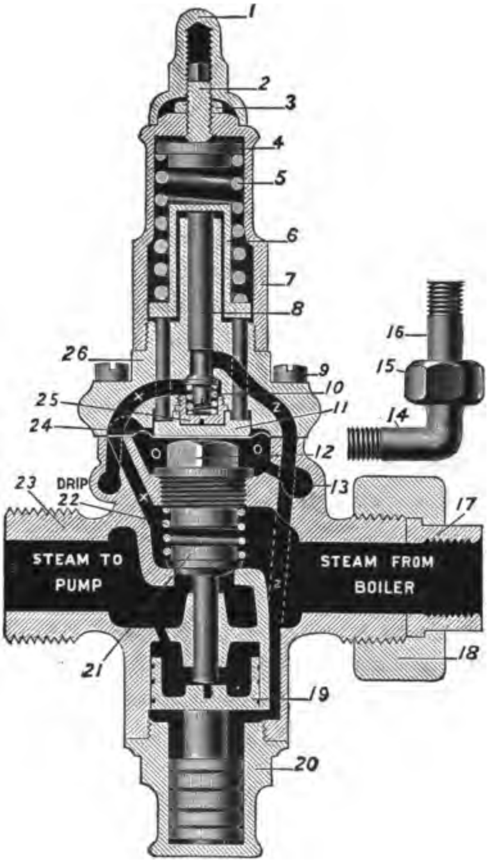

FIG. 139.

pressure in the brake-pipe is reduced by applying the brakes the pump will quickly produce a surplus pressure in the main reservoir to insure the speedy release of the brakes and recharge the auxiliary reservoirs. The piston 19 is fitted with a dash-pot, which prevents chattering or pounding when the air-pressure is suddenly reduced.

Directions for Attaching the Regulator.—Place the regulator in the steam-supply pipe to the pump, and so that steam will flow through it in the direction indicated by the arrow cast on the body. With a small pipe make a connection from the train-pipe to the air-pressure connection 15 and 16 on regulator. The one-eighth-inch tapped hole marked "Drip" must be left open, but it may drip from either side by reversing the plug.

Before connecting the regulator to pump, the steam-pipe should be thoroughly blown out, in order to expel all dirt. If the piping is new, steam should be allowed to flow through slowly for some little time, in order to burn off all gummy oil and grease, which would otherwise be carried into the regulator, and thus clog the working parts.

When ready to start, open both steam and air valve wide, then remove the cap 1 which screws over the screw 2, slack off the jam-nut 3, and with the key gradually screw down the adjusting screw 2 until the desired air-pressure is obtained. The regulator is then properly set. Screw the jam-nut 3 down firm and replace the cap 1.

If the regulator should fail to hold the desired pressure, it will probably be due to the fact that some dirt or chips from the pipe have lodged on the seat of the main-valve 21, or possibly under the auxiliary-valve 8.

To open the regulator proceed as follows: Shut off both steam and air pressure from the regulator. Remove the cap 1, and with the key unscrew the adjusting-screw 2 until all tension is removed from spring 5. Then take out the screws 9, and remove bonnet 7, diaphragm 14, and button 11. Take out the plug 12 and the spring 22. The threaded rod which accompanies each regulator can then be screwed into valve 21, which should work easily. Pull out this valve and examine both valve and seat, cleaning them thoroughly. Then insert the rod through the valve-stem guide, screw it into the piston 19, and see if it works up and down easily. It will not be found possible to raise it suddenly, as the dash-pot piston 20 will restrain it. After pulling up, let go of the rod suddenly, and if the piston drops easily it is all right. In case it does not, unscrew the dash-pot cap 20 from bottom of the regulator, pull out the piston 19, and clean it with kerosene or spirits. If it seems somewhat tight, rub it with fine emery-cloth, being very careful to thoroughly wipe it off before replacing. Before screwing on the bonnet, examine the auxiliary-valve 8. To do this, remove the slot-headed plug 25 in bottom of bonnet, also the small spring 10. The valve 8 can then be taken out and examined. This valve should work perfectly free. In taking out the plug 25 there may be a burr, caused by the screw-driver, which should be dressed down before replacing, as this plug forms a guide to centralize the diaphragm button 11, which should fit over it freely. In replacing the bonnet 7, be sure that the zero-marks on the side and those on the body correspond; also see that the diaphragm 24 is replaced so that the port-holes in it correspond with the holes in the body. Carefully clean the diaphragm as well as the place where it makes its seat. Do not use washers or gaskets of rubber, or any other compound, in making connections. They will burn, and the pieces will get into the regulator. Two copper gaskets are sent with each regulator for making the steam connections.

THE NEW YORK AIR-BRAKE SYSTEM.

The New York Air-brake is perfectly interchangeable with the Westinghouse equipment, and cars equipped with either brake can be indiscriminately mixed in a train and handled with equal facility by the engine equipment of either system; or a New York air-pump, triple-valve, etc., can be used in connection with the Westinghouse apparatus, and *vice versa*. This perfect interchangeability permits any railroad company to adopt the New York Air-brake apparatus either wholly or in part without interfering in any way with its method of operating, and thus the greater efficiency and durability of the New York apparatus can be readily secured without incurring the annoyances which would ensue if the brake were not interchangeable with the Westinghouse system now in general use.

The New York Quick-action Air-brake consists of the following principal parts:

1. The *Duplex Pump*, which compresses the air. The duplex action is extremely easy working, and gives much greater efficiency than the ordinary single-acting

pump, while the construction is very simple, and every valve can be readily examined by unscrewing a plug. The advantages of such simple construction, both in convenience and durability, are evident. Another advantage is that the steam-cylinders are at the bottom, and therefore the drainage is perfectly natural, while the air-cylinders are above the steam-cylinders, thus insuring clean and dry air, as impurities and the condensation from steam-cylinders cannot leak into the air-chambers.

2. The *Main Reservoir*, in which the compressed air is stored on the engine, and in which a greater pressure is maintained than in the other reservoirs or train-pipe to assist in releasing the brakes promptly.

3. The *Engineer's Equalizing-discharge Brake-valve*, which regulates the flow of air into the train-pipe and auxiliary reservoirs to charge the train and release brakes, and from the train-pipe to the atmosphere for applying brakes. The New York Engineer's Valve is less complicated, and its operation easier to understand than the valves heretofore used, and is so constructed that the use of a separate "equalizing-reservoir" is entirely avoided.

4. The *Train-pipe*, which leads from the main reservoir to the engineer's-valve, and thence throughout the train, supplying air to the apparatus on each car. Variations of the pressure maintained in the train-pipe causes the apparatus on each car to operate so as to apply or release the brakes.

5. The *Auxiliary Reservoir*, which receives air-pressure from the train-pipe, and stores it for use on each car

or engine, the air being allowed to pass into the brake-cylinder when an application of the brakes is desired.

The brake-cylinder, which forces the shoes against the wheels when air-pressure from the auxiliary reservoir is admitted against the piston, the end of the piston-rod being suitably connected to the brake-levers. Around the piston-rod, inside of the brake-cylinder, is a large spring, which is compressed by the action of the piston when applying brakes, and which expands when the brakes are released, thus causing the piston to recede to its former position and draw the shoes away from the wheels.

7. The *Quick-action Automatic Triple-valve*, which is connected to the train-pipe, auxiliary reservoir, and brake-cylinder, and is so constructed that variations of pressure in the train-pipe will operate it, causing a moderate application of the brakes or an instantaneous and forcible application, as desired. The operation is as follows: When the train-pipe pressure is reduced five pounds or more the auxiliary reservoir is cut off from the train-pipe, and air-pressure is admitted from auxiliary reservoir into the brake-cylinder proportionately to the reduction of train-pipe pressure. A sharp reduction of the train-pipe pressure of fifteen or twenty pounds produces the same effect, and also admits air direct from the train-pipe into the brake-cylinder, thus applying the brakes instantly, and with about 20 per cent greater force than when the train-pipe pressure is not utilized in this manner. The quick reduction of train-pipe pressure at each car by this means rapidly operates the valves on succeeding cars, so that the

action of all brakes in the train is practically instantaneous.

The following are also parts of the brake equipment:

The Plain Triple-valve, which is used only on engine and tender. It is of the same construction as the quick-action valve previously described, except that the emergency or quick-action parts are omitted, leaving only the service mechanism.

As the valves on locomotive and tender are always the first to receive pressure, and it is not desirable to have the locomotive and tender brakes operate before those on the train, the plain triple-valves are always used here, as they answer the requirements perfectly.

The Pump-governor, which regulates the amount of steam supplied to the pump, and shuts off steam when the maximum air-pressure has been accumulated in the train-pipe and reservoirs.

The Duplex Air-gauge, which shows simultaneously the pressure in the main reservoir and in the train-pipe.

The Conductor's Valve, which is placed in passenger cars and connected with a cord running the entire length of the car, so that any of the trainmen, by pulling this cord, can open the valve, which allows the air to escape from the train-pipe and apply the brakes. It is intended for use only when it is desirable or necessary to stop the train without depending upon or waiting for the engineer to do so.

The Couplings, which are attached to rubber hose, and connect the train-pipe from one car to another.

The Pressure-retaining Valve, which is used upon freight cars for retaining about fifteen pounds pressure in the brake-cylinders while descending heavy grades. It is a weighted valve of such size that fifteen pounds pressure is required to raise it, and is connected by suitable piping to the exhaust-port of triple-valve. It is provided with a small cock, and when handle is placed in horizontal position the air issuing from exhaust-port of triple-valve when brakes are released has to lift the weight before escaping to the atmosphere, and as this does not affect the working of the triple-valve, the brakes will remain on and check the speed of train while the auxiliary reservoirs are recharging. With handle turned down the brakes release as usual, the escaping air having a free passage to the atmosphere without passing the weighted valve.

DUPLEX AIR-PUMP.

Fig. 140 shows the No. 1 duplex air-pump, which is adapted for passenger and light freight locomotives. The duplex action is extremely easy, and gives much greater efficiency than the ordinary single-acting pump.* The steam-cylinders are underneath the air-cylinders, which allows natural drainage and insures clean, dry air, as impurities and the condensation from steam-cylinders cannot leak into the air-chambers. The action of the pump in compressing air is similar to that of using steam in a compound engine, and results in a corresponding economy; both steam-cylinders and the high-pressure air-cylinder are 5″ in diameter. The low-pressure air-cylinder is 7″, and is twice the capacity of the steam-cylinder that actuates it. In

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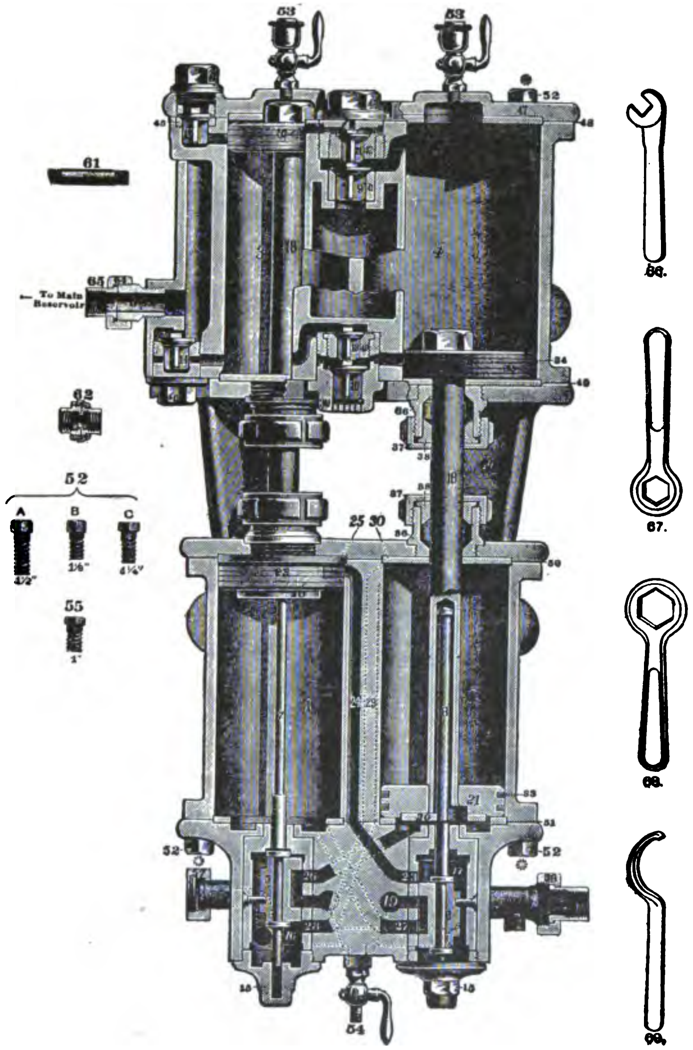
* Manufacturer's claim,


53
53
52
47
48
49
61
65
64
← To Main Reservoir
4
18
62
52
A
B
C
1/2"
1/4"
1 1/4"
55
1"
66
37
38
25
30
36
50
21
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51
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66.
67.
68.
69.

FIG. 140.

operation both air-cylinders are filled with free air. The high-pressure piston remains quiet until the air from the large cylinder is compressed into a small cylinder, then the high-pressure piston completes the compression and forces the air into the reservoir. Thus two measures of steam compress three measures of air. The valve-gear for the steam-cylinder consists of two plain slide-valves 5 and 6, moving in steam-chests 16 and 17, and operated by small tappet-rods 7 and 8, which extend into the hollow piston-rods of the steam-cylinders. As is shown, the valve on one side controls the supply of steam on the opposite side.

The following description will make clear the action of the pump:

In the position shown, the air-piston in cylinder 4 has completed its downward stroke, and compressed its contents through valve 12 into cylinder 3. The plate 20 on steam-piston 21 has moved valve 6 to its lowest position. This admits steam through ports 23, 24, 25 to upper side of piston 22, and will cause that piston to descend and expel the partially compressed air in cylinder 3 through valve 14 and passage shown into the reservoir. Meanwhile the cylinder 4 has become filled above the piston with air at atmospheric pressure through valve 9, and the cylinder 3 will be filled with air at atmospheric pressure through valves 9 and 11, both of which open inward and are seated by gravity. When piston 22 reaches the end of its downward stroke the plate 20 strikes the tappet on valve-stem 7 and moves valve 5 to its lowest position, thus uncovering port 26 and admitting steam through port 26 to the lower side of piston 21, thus causing piston 21 to rise and compress the air which is in cylinder 4, through valve 11 into upper part of cylinder 3. Just as piston 21 completes its stroke, its plate 20 strikes the tappet on valve-stem 8 and moves valve 6 to its highest position, uncovering port 27 and admitting steam through port 27 to the lower side of piston 22, causing that piston to rise and expel the partially compressed air in cylinder 3, through valve 13 into passage shown, and thence into the reservoir.

While the pistons are compressing the air above them into the reservoir, the air-cylinders below the pistons will be filled with air at atmospheric pressure through valves 10 and 12 ready for another cycle of operation. The duplex construction makes it possible for the valve-gear to be extremely simple. The air-valves are simple poppet-valves, which seat by gravity while the pistons wait, and therefore are not liable to pound themselves to pieces. All parts of the pump are durable and easily accessible. Steam and air valves may be examined by unscrewing plugs without taking down the pump.

PUMP-GOVERNOR.

Fig. 141 shows the construction of the pump-governor. Its purpose is to automatically shut off the supply of steam to the pump when the air-pressure in the train-pipe and auxiliary reservoirs has reached the desired limit. The brake-gear used on cars and engines is designed for a maximum air-pressure of 70 pounds in train-pipe. This limit should not be exceeded.

Referring to the illustration, the steam-valve 5 is opened by steam-pressure, but is closed by air-pressure on top of piston 4 when the train-pipe pressure has

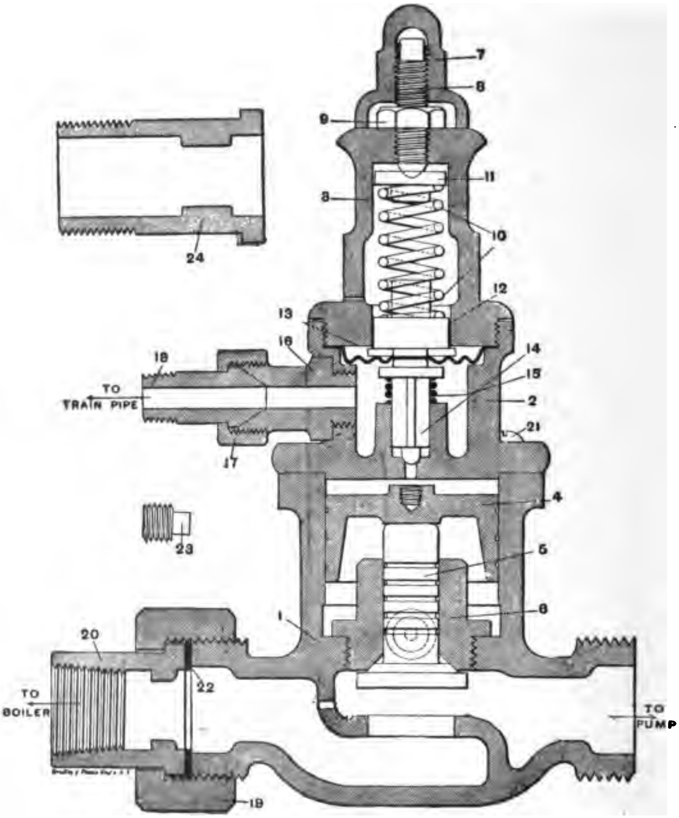


FIG. 141.

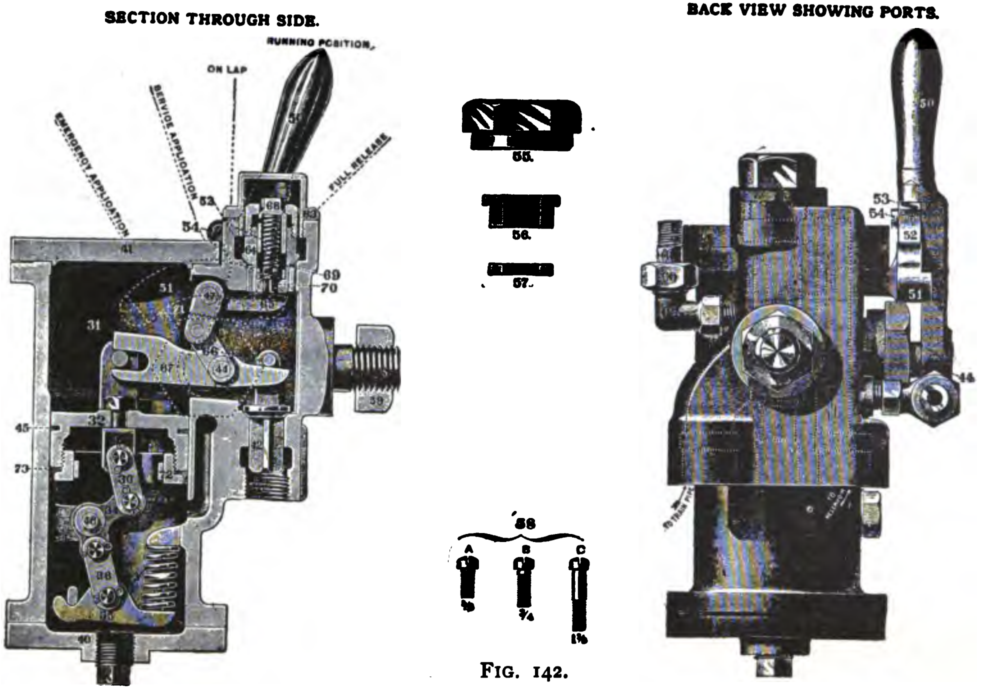
reached the limit for which the governor is adjusted. The action of the train-pipe pressure is controlled by diaphragm 13 and spring 10. When the train-pipe pressure underneath the diaphragm overcomes the tension of spring 10, the diaphragm will rise and allow valve 14 to open the train-pipe pressure to the top of piston 4. When the train-pipe pressure becomes less than the desired limit the spring 10 will close the valve 14. The air above piston 4 will then leak by the piston and allow the steam-pressure to open the steam-valve 5. An opening is provided in the chamber under piston 4, for any leakage of steam or air. Any necessary adjustment of the regulating spring 10 may be made by means of screw 8 and lock-nut 9. In order that steam may keep the exhaust from freezing, a small hole above the steam-valve is always open.

Instructions.—Place the pump-governor in the steam-supply pipe leading to the pump, so that steam will flow through it in the direction indicated by the arrow. The end of the governor which goes toward the pump is made to fit the union connection furnished with the pump, and as a rule it is best to attach the governor here. Do not use rubber gaskets in making connections. Connect the quarter-inch union in the upper part of the governor with the train-pipe. After piping up, but before connecting in the governor, blow out both steam and air-pipes, to expel any dirt or scale which may be in the pipes. Two leakage or drip holes, tapped to take $\frac{1}{8}$-inch pipe, are provided in the body of the governor. One of these holes must always be left open, but the other one may be plugged.

ENGINEER'S VALVE.

Fig. 142 shows the Engineer's Valve. The different positions of handle are "release," "running position," "lap," "service," and "emergency," corresponding to the effect produced with the handle standing in those positions.

The following description will make its operation plain: The chamber above piston 32 is connected with the train-pipe; the chamber below the piston is connected with the main reservoir. Exhaust-valve 42 regulates the discharge of air from the train-pipe. It is opened by handle 50, but closed automatically by piston 32. Lever 67, which is fulcrumed on eccentric-pin 44, is for opening valve 42. Lever 65, which is fulcrumed on pin 47, and connected to eccentric-pin 44 by link 66, is for opening main feed-valve 64 and small feed-valve 70. To apply the brakes, the handle (which is attached to the spindle that carries the eccentric-pin 44) is moved beyond the second notch (lap). This raises the outside end of the lever 67, and with it valve 42, thus allowing air to escape from the train-pipe, as the pressure tends to raise the inside end of lever 67 and allow valve 42 to close and stop the escape of air from the train-pipe. If the eccentric-pin is raised but a little, the piston will have to rise but little to close the valve. If it is raised higher, the piston will need to rise higher to close the valve, and consequently will allow more air to escape from the train-pipe before the valve closes. This piston is made automatic in its action by means of the bell-crank 34 and spring 33.



SECTION THROUGH SIDE.

BACK VIEW SHOWING PORTS.

FIG. 142.

The pressure of the spring holds the piston down as long as the pressure on both sides of the piston is the same, but with a very short leverage on the bell-crank. The piston is connected to the bell-crank with a much longer leverage so that a very slight difference in pressure on the piston will allow it to start upward, but as it ascends the piston leverage decreases and the spring leverage increases until an equilibrium occurs and the piston stops. A further reduction on the upper side of the piston will cause the piston to travel still farther upward. It follows that the reduction of pressure in the train-pipe caused by opening the valve 42 will depend on the height the eccentric-pin 44 is raised by the handle, as the piston must rise a corresponding distance to close the valve, and the distance of piston travel depends on the difference in pressure on its opposite sides.

To release the brakes the handle is moved forward the full length of its stroke. This causes eccentric-pin 44 to descend, allowing the outer end of lever 67 to clear the lifting-pin in valve 42, so that it will be held to its seat by the train-pipe pressure above it. As lever 65 is connected with eccentric-pin 44 by link 66, this movement also causes it to rotate and lift main feed-valve 64, admitting full reservoir-pressure to the train-pipe; the chamber above feed-valve 64 being in direct communication with the main reservoir. When the handle is brought to running position or first notch from full release, main feed-valve 64 is closed, while small feed-valve 70 remains open, and air from main reservoir can get to train-pipe only by passing through excess-pressure valve 68, by compressing spring 69, and thence through small feed-valve 70 to train-pipe. In the running position the pressure in train-pipe is kept from 20 to 25 lbs. lower than main-reservoir pressure.

When handle is brought to lap position or second notch from full release, main feed-valve 64 is closed, together with small feed-valve 70, and in this position no air can get from main reservoir to train-pipe ; or, in other words, the train-pipe is blanked from main reservoir.

PLAIN TRIPLE-VALVE.

Fig. 143 shows a section of plain triple-valve which is used only on engines and tenders. The parts are few, simple, and durable, and their operation is not easily affected by dirt. Connections are made with the auxiliary reservoir, the brake-cylinder, and the train-pipe, as shown. Slide-valve 38 controls the exhaust of air from brake-cylinder to release brakes, and graduating-valve 48 controls the admission of air from auxiliary reservoir to the brake-cylinder for applying brakes. Piston 40 actuates slide-valve 38 and graduating-valve 48, and in such a manner that valve 38 will close exhaust-port before graduating-valve 48 is opened. The slide-valve 38 can remain stationary while the piston 40 returns part way and closes graduating-valve 48, as the abutments that move valve 38 are farther apart than the length of the valve.

The operation is as follows: Air from the train-pipe passes to cylinder *A*, and thence through passage *B* and *C* to chamber *D*, and then through passage *E* to the auxiliary reservoir. When the train-pipe pressure is reduced the piston 40 moves its full stroke, first shutting off the auxiliary reservoir from the train-pipe by

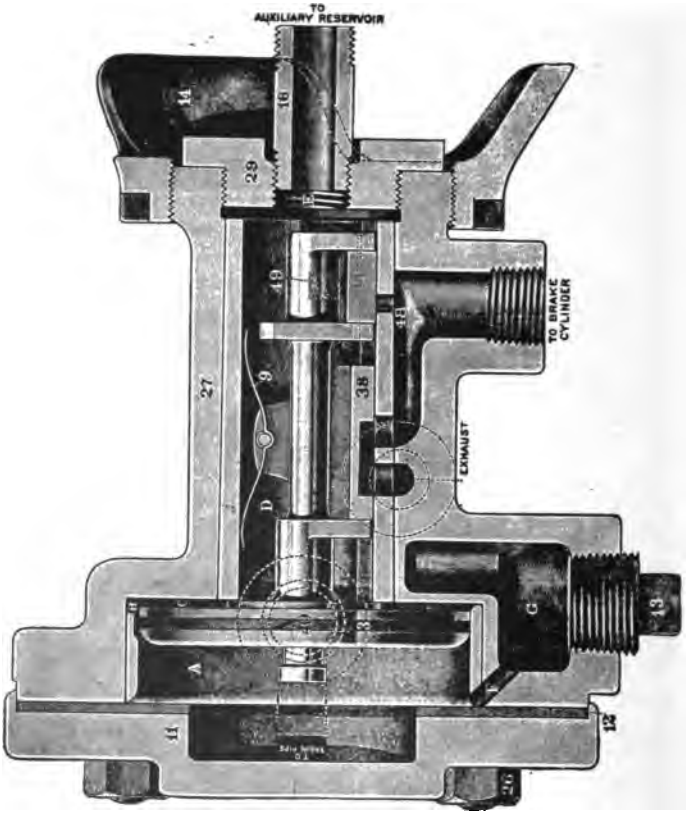


FIG. 143.

closing the connection between passage *B* and cylinder *A*, next closing exhaust-valve 38 and opening graduating valve, 48 which will admit air into the brake-cylinder, the amount admitted being in proportion to the reduction of the train-pipe pressure. If the train-pipe pressure is reduced but little, the pressure in the reservoir is soon reduced to less than that in the train-pipe, and the piston 40 starts back and closes graduating-valve 48 without disturbing slide-valve 38, which is held with some force by the air-pressure, aided by spring 9, and checks the return-stroke when valve 48 is closed. A further reduction of train-pipe pressure would repeat the same action and apply the brakes a little harder. If the train-pipe pressure is reduced 5 to 8 lbs. the brakes will be applied with but moderate force, but if the train-pipe pressure is reduced 20 lbs. the graduating-valve 48 will remain open and the brakes go full on, as the auxiliary-reservoir pressure will then continue to flow into the brake-cylinder until the pressure in each is equalized. An increase of pressure in the train-pipe will cause all the valves to move back to the position shown in the plate, thus releasing the brakes and allowing the reservoir to be recharged.

Passage *F* allows moisture from the train-pipe to collect into chamber *G*, where it can be readily drained by unscrewing plug 13.

Fig. 144 shows a section of the quick-action triple valve, the upper part of which is a duplicate of the plain triple-valve. For ordinary service stops the quick-action parts shown in the lower half of the cut remain inoperative, and the upper part operates in precisely the same way as the plain triple-valve, admitting auxiliary-reservoir pressure only to the brake-cylinder. The quick-action parts are for the purpose of giving a more powerful action of the brake than is necessary in ordinary service, and in emergencies, where such powerful action is needed, they admit additional pressure direct from the train-pipe through a comparatively large

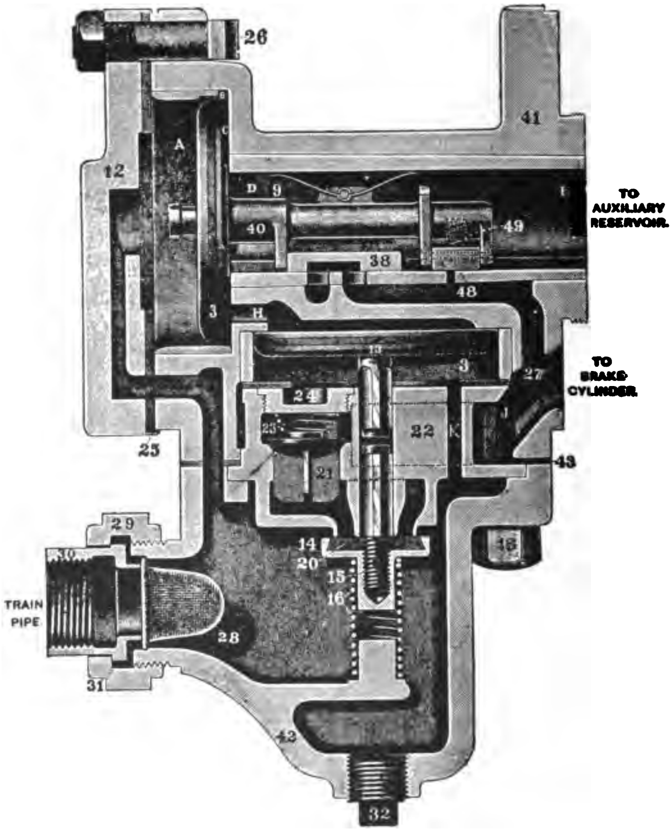


FIG. 144.

opening to the brake-cylinder, thus reinforcing the pressure derived from the auxiliary reservoir. The parts are few, simple, and durable, and have been improved so that the operation of the graduating and emergency features is unfailing on trains of any length and under any conditions of service. They have been thoroughly tested in the shops and in actual use on 50-car freight trains, demonstrating their reliability under most unfavorable conditions.

The emergency or quick-action portion consists of three moving parts; 1st, a valve 20,* controlling a passage from the train-pipe to the brake-cylinder; 2d, a piston 13 for actuating valve 20; 3d, a check-valve 21 to prevent air in brake-cylinder from passing back into the train-pipe. Valve 20 is held on its seat partly by spring 16, but principally by train-pipe pressure on its under side. Piston 13 is open to reservoir pressure on its upper side, through passage *H*, and to train-pipe pressure on its lower side through passage *K*. In order to open valve 20 it is necessary to decrease the train-pipe pressure so much that the sum of the upward pressures on valve 20 and on piston 13 is less than the amount of reservoir pressure on the top of piston 13. A quick reduction of 10 lbs. or more in the train-pipe pressure causes piston 13 to move down and force valve 20 from its seat, allowing the train-pipe pressure to lift and pass under check-valve 21, and through passage *J* directly into the brake-cylinder, thus quickly reducing the train-pipe pressure to actuate valves on succeeding cars, at the same time applying the brakes with greater force than would be possible if the brake-cylinder received air from the reservoir only. Check-valve 21 will close as soon as the brake-cylinder pressure is as high as that in the train-pipe, and the brake-cylinder pressure will be increased from the auxiliary reservoir through valve 48.

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* To get the proper names of the different parts of the brake mechanism, look to the numbers given in the text and drawings.

To release the brake the train-pipe pressure is restored. This raises piston 13 and allows the spring to seat valve 20 before piston 40 has sufficient force to overcome the resistance of slide-valve 38 and cause it to return to the position shown and thus release the brake.

Moisture from the train-pipe collects in the bottom of the valve, where it can be easily drained by unscrewing the plug.

WORK REPORTS.

Locomotive engineers and firemen should try to become familiar with each part of the locomotive mechanism, as the parts are constantly increasing, due to improvements; and the question is often asked, What shall I call this or that part which is broken, when a work report is to be made out. It is much better for those in charge of the repairs to know from the report of the engineer just what part is broken, instead of having to guess, or get the inspector to look for it; and in a measure the work report will show the engineer's knowledge of the machine he controls. The work reports given on the next page are not fictitious but those respectively of an engineer who is progressive and of one who is not so inclined.

I.

Sy. Div., Jan. 15, 1893. 10.20 A.M.

(Engine Track.)
Buddly sock lost off the Jumbo.
Have flues corked.
Piston-packing wants to be fixed.
Air-pipe is busted somewhere under foot-board; have the inspector look for it.

Safety valve { lifts at 165 lbs.
seats " " "

John Amos, Engineman.

II.

Sy. Div., Jan. 15, 1893. 10.20 A.M.

(Engine Track.)
Cinder hopper-cap lost.
Have flues calked; leaking in bottom row.
Piston-rod packing-rings broken on right side.
Air-pipe leading from main brake-pipe to auxiliary reservoir on the engine burst near the triple-valve.

Safety-valve { lifts at 165 lbs.
seats " 160 "

Thos. Allen, Engineman.

Report I is made out by a man who doesn't care to read any books about his business or keep posted on improvements. All that he desires is that pay-day shall come once a month.

Report II is made out by a progressive man, who believes that he can advance himself by reading and keeping abreast of the improvements in his business.

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